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I

Introduction

The C.S.I.R.O. Twelfth Annual Report (for the year 1959–60) was prepared in a different form from earlier annual reports. To reduce the time spent in preparation so that it could be available for presentation to Parliament early in August, at the time of the introduction of the Budget, it was considerably shortened in length. Apart from information of a general administrative nature this document reported only the highlights of the research program. These were dealt with in popular language, as it had long been felt that the earlier annual reports were too technical in style, and their coverage too voluminous, to be of value and interest to the general public.

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The purpose of this Research Review is to present the scientific details of the research program in much the same way as the earlier annual reports. By its nature it is of course primarily of interest to the scientific community, but it will also serve as a work of reference to those of the general public wishing to check on particular aspects of C.S.I.R.O. activities. In either case it should be read in conjunction with the Twelfth Annual Report, the two publications together forming a comprehensive record of the Organization's work and activities for the year 1959–60.

Each chapter has been devoted broadly to one Division or Section of C.S.I.R.O. Rather than placing the chapters in alphabetical order of the Divisions and Sections, they have been arranged in a more logical sequence with those on the primary or agricultural side first, followed by those with greater relation to the secondary or manufacturing industries.

Since the research programs of the various Divisions and Sections overlap in many fields of study, care has been taken at the beginning of each chapter to indicate those other establishments of C.S.I.R.O. where research is in progress on closely allied projects.

Details of general administrative matters, lists of professional staff, published scientific papers, and financial details for the year are included in the Twelfth Annual Report.

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Division of Soils

1. General

The Division of Soils is the main centre in C.S.I.R.O. for research on soils. Its headquarters are at Adelaide, but its interests are Commonwealth wide. The activities of the Division in other States are conducted through regional centres at Brisbane, Canberra, Perth, and Hobart, and through subregions at Armidale, Griffith, and Deniliquin in New South Wales and Alice Springs in Northern Territory.

Research on the engineering aspects of soils which is undertaken at the Soil Mechanics Section, at Syndal, Vic., is described in Chapter 22.

Work on soils with special reference to their behaviour under irrigation is undertaken at the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Vic., and at the Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, N.S.W. (*see* Chapter 5), at the Regional Pastoral Laboratory, Deniliquin, N.S.W. (*see* Chapter 3), and at the Kimberley Research Station and the Coastal Plains Research Station (*see* Chapter 13).

During the year under review there has been consolidation of the new system of decentralization within the Division of Soils which was initiated in 1959, whereby a greater degree of research autonomy was given to regional groups in Brisbane, Canberra, Perth, and Hobart under an officer-in-charge as research leader.

Greater attention has been paid to applied research dealing with soil fertility in the broad sense of soil as a medium for plant growth. An experimental series of field trials was begun in New South Wales in an endeavour to relate the properties of different soil types with pasture plant response under irrigation and with similar fertilizer treatment. The variable in this assessment of fertility is thus the soil type. Attempts are being made on a wide array of soils to score their fertility status by glass-house pot tests, by field trials, and by use of chemical extractants. This is to supply the link between soils mapped in surveys and their edaphic character.

Erection of the second laboratory at Adelaide has begun and when complete this will, for the first time in their history, bring all Sections of the Division on to one campus. An ancillary building also at Adelaide headquarters to serve as store and laboratory has been completed and will be occupied initially by a regional unit of the Soil Mechanics Section. The Brisbane regional unit moved into the new Cunningham Laboratory in association with the Division of Tropical Pastures.

During the year two officers left Australia on study leave, two are on C.S.I.R.O. Overseas Studentships, and three are on scholarships or other grants in Britain and America.

The Soil Physics Section has been pleased to offer laboratory accommodation for 3 months to Dr. C. W. Rose, on sabbatical leave from Makerere College, Uganda.

In the following statement concerning research during the past year the regions have been dealt with separately as units integrating the work of all Sections at each centre to show the scope of investigation covered.

2. Soil Survey and Pedology

(*a*) *General*

This section of the report of the Division of Soils details research concerned with soil survey and pedology undertaken by staff stationed at the headquarters of the Division in Adelaide. Further soil survey and pedology research undertaken by the Division of Soils in other regions of the Commonwealth is described later in this chapter.

Completion of a long-standing investigation of a laterite area in the inner wheat belt of Western Australia between York and Quairading has shown that an intricate but systematic relationship exists between several lateritic and non-lateritic soils. This relationship augments knowledge gained by earlier research into the fossil nature of laterite and the soils resulting from its dissection.

Another investigation completed at Merredin in the outer wheat belt shows that the solonized brown or mallee soils which make up part of the soil pattern there have been derived by aeolian action from the beds of the salt lakes which are remnants of a former more active stream system. It is clear that rather more than a common origin must be sought for all the mallee soils in southern Australia.

At the request of the International Society of Soil Science a new soil map of Australia has been compiled on a scale of 1 in 2½ million, and is being printed at 1 in 5 million. This map will be exhibited at the VIIth International Congress in Soil Science at Madison, Wisconsin, U.S.A., in August 1960, along with new soil maps of the other continents. The map provides a new basis for the broad estimation of Australia's soil resources and for teaching basic soil geography and genesis. It has also provided new information about the nature and distribution of some soils, including the extensive arid red earths shown for the first time on a map of this type. With the new information about mallee soils from Western Australia it helps to discard two earlier hypotheses on the origin of the great quantities of lime in these soils.

The first sheet of an Atlas of Australian Soils covering the lower part of South Australia, western Victoria, and south-western New South Wales has been compiled and is in press. Work is proceeding with the second sheet covering the remainder of Victoria, the south-eastern part of New South Wales, and all of Tasmania.

(*b*) *South Australia*

Work continued on the two field mapping projects in the Mount Crawford Forest Reserve and in the Counties Robe and Macdonnell in the south-east of South Australia. Investigations directly concerned with soil genesis continued but the work mainly concerned soils in relation to land use.

A power-driven soil-core sampler, specially developed during past investigations in the Elizabeth township area near Adelaide, was the subject of a short school attended by officers from several regions where this machine may be used. The machine weighs about 15 cwt and may be mounted on to a light vehicle equipped with power take-off; it has been used to produce cores of either 2 or 6 in. diameter from depths up to 12 ft.

The Mount Crawford Forest Reserve near Adelaide, where detailed mapping was continued in this period, experienced exceptionally dry conditions in 1959 and as a result progress in the field work was retarded. But apart from the hardness of the soils, detailed mapping of uniform soil types proved most difficult even on quite a large scale in this complex area, much of which is well covered by forest growth and undergrowth. The mapping program has therefore been revised, and the whole area is to be mapped as soil complexes, which should represent the soils of the area satisfactorily.

The field work of a reconnaissance soil survey of Counties Macdonnell and Robe in south-east South Australia was completed. This part of the south-east, including Naracoorte, Kybybolite, Padthaway, Lucindale, Robe, and Kingston, is marked by alternating flats and ridges associated with former coastlines. Clearing of native vegetation, sowing of pastures, land drainage, and road construction have all had great attention there in the past decade. The soil map to be issued for these parts should be of value to those concerned with the future problems of local land use.

Attention has been given both in western Victoria and adjacent parts of South Australia to sandstones, frequently quite ferruginous, which are exposed sporadically in a large part of the Murray Basin plains. This investigation, in collaboration with the Soil Chemistry Section, is expected to provide deeper knowledge of dune formations and soil genesis in this region.

3. Soil Chemistry

This section of the report of the Division of Soils details research concerned with soil chemistry undertaken by staff stationed at the headquarters of the Division in Adelaide. Further soil chemistry research undertaken by the Division of Soils in other regions of the Commonwealth is described later in this chapter.

(i) *Potassium Studies*

Work on the fractionation of potassium and its availability in a Tasmanian podzolic soil and in a red-brown earth in South Australia has been completed.

The small release of potassium on continuous cropping of the Tasmanian soil was related to the very small reserves of difficultly available potassium in the samples examined. The supplies of exchangeable potassium were rapidly depleted by cropping, and responses to added potassium then became marked. The amount and composition of the minerals of the clay fraction explained the poverty of these soils in reserves of potassium. Extraction with hot nitric acid gave a satisfactory evaluation of these reserves which could slowly augment the supplies of exchangeable potassium available for plant growth. The potassium status of the red-brown earth loam was very different. In this soil, the illite of the clay fraction represented a big reserve of difficultly available potassium, which was released as the more available exchangeable potassium was partly depleted. Because of this relatively rapid release of difficultly available potassium from the illite, four successive crops reduced the level of exchangeable potassium to only half its initial value. Extraction with hot nitric acid again reflected these reserves and their rate of release under cropping.

In another project the structural potassium in soil illites is being studied as a source of potassium to plants. Chemical analyses have shown that the availability of non-exchangeable potassium in the selected soils is related to the degree of degradation of the illite structure and to the potassium content of the clay fraction but not to the total soil potassium.

Large quantities of the clays from these soils have been separated and their exchangeable potassium has been removed. These materials are being used as sources of structural potassium, so that its availability may be compared with sources of exchangeable and soluble potassium. The natural soils cannot be used for this purpose because the sand and silt fractions are also rich in potassium.

These glass-house experiments are being paralleled by laboratory studies of the reactivity of potassium in purified soil illites, and of other aspects of the chemistry of these clays.

(ii) *Residual Phosphorus*

The field experiment designed to measure changes in the residual value of superphosphate for a number of years after its application was continued for a further season because of the virtual failure of the crops in the severe drought of 1959. Appraisal of the residual value by the pot experimental approach is also being continued and soil samples from the different plots are being examined by various extractants to determine the amounts of phosphate remaining 12 years after the last application of superphosphate. Crop analysis shows that phosphate removal from the control plots still represents only a small fraction of the fertilizer residues at the commencement of the experiment.

(iii) *Fertility Rating of Soils*

A program commenced in the laboratory and glass-house to assess the general fertility level of South Australian soils. Investigations will later be carried out on the more important soil types as they are defined and mapped. Because of lack of staff for this project it has been possible to undertake only a preliminary pot investigation on three soils, all of which were from the Hundred of Kuitpo.

Phosphorus, nitrogen, and molybdenum deficiencies were noted and a structural problem was apparent by the results on one of the soils. Subterranean clover and New Zealand perennial ryegrass were used as the test plants.

(iv) *Nutrition of Pines*

A series of pot experiments on the addition of superphosphate and ammonium nitrate to *Pinus radiata* growing on a lateritic ridge soil from Second Valley is now at the end of its second year. Some of the fertilized trees show phosphate deficiency symptoms very similar to symptoms found in the field, viz. death of the lower needles on the branches as the phosphate is moved to the growing tips, and yellowish brown needles at the tips. Analyses of needles and branches have established levels below which phosphate deficiency occurs, and samples have been collected from the forest area to enable these levels to be extended to the field. It will then be possible to analyse needles or branches in order to diagnose phosphate stress. Although placement studies of superphosphate gave trees of equal height after the first year, the phosphate content of the needles was found still to be influenced by placement after nearly two years. The needles contained less phosphate when it was placed more deeply in the pot. With the addition of heavier superphosphate dressings nitrogen fertilizer continued to improve the vigour of growth. This was especially reflected in increased needle length. The use of Rhenania phosphate instead of superphosphate seemed to give a more sturdy tree.

Pots established in 1959 included treatments with phosphate, nitrogen, potassium, calcium, sulphur, magnesium, and trace elements. At the present time, very small amounts of superphosphate have not greatly improved the growth of young seedlings. There may well be a threshold level for significant responses to superphosphate. Results on the pallid zone material from the lateritic profile (similar to the soils on the middle slope sites) indicate definite responses to these small amounts of phosphate but show a severe nitrogen deficiency. This is in agreement with the appearance of the trees in some areas of the forest.

(v) *Pedological Studies*

Fungal hyphae have been observed in many soils, particularly sands, and these organic filaments appear to play an important part in aggregation of soil particles. The occurrence of these fungal filaments was first noted in seeking the cause of poor reproducibility in sand fractionation. Examination of the sands separated from certain soils showed that the sand grains were frequently attached to fine fungal filaments, and until these filaments were destroyed the individual grains were prevented from passing the sieves. The filamentous binding had withstood the rather drastic treatment normally given to soils to bring about proper dispersion. The widespread occurrence of these filaments has been noted in soils generally, but most work so far has been done on sandy soils. Stabilization of many sandy surfaces can be ascribed to fungi. A modification of the wet sieving technique has been developed to assess the degree of aggregation.

Only limited progress has been made on the field study of the solodized solonetzic soils at Mount Crawford because of the abnormally dry winter of 1959. At no time was the usual perched water-table present and many of the *in situ* studies were deferred until more normal conditions prevailed. The salt profile was examined under the dry conditions; increases of two to fivefold occurred in the top 1½ in. of the B horizon.

A re-examination of the chemical characteristics of terra rossas and rendzinas has been made. One of the discriminant functions of mathematical statistics has been used in an attempt to obtain a means for the chemical discrimination of the two groups. It was found that terra rossas and rendzinas constitute a bimodal group chemically, and dichotomy is therefore justifiable on chemical as well as on morphological grounds. A number of extra-Australian samples of these soils were also examined in the course of this investigation. The discriminant functions that were successfully used to separate the Australian samples could be used equally well to separate the extra-Australian samples. All these soils had been classified on morphological grounds. This result strongly suggests that soils which are alike morphologically are usually alike chemically, whatever the country of origin.

It seems obvious that the trace element profile of a soil, the graph obtained by plotting concentration of element against depth, should provide information on the processes by which the soil reached its present state of development. The interpretation of such a profile has, however, proved very difficult mainly because it is impracticable to determine which features are fundamental and which are accidental. A simple procedure has now been devised by means of which trace element profiles for soils of one taxonomic group may be combined to form an average profile for these soils. Because the accidental features of a profile are unlikely to be the same for any two soils, these features are suppressed in the average profile while the fundamental features are accentuated. Current work on such average trace element profiles for some red-brown earths clearly indicates that useful information on the pedological history of these soils, and of the trace elements themselves, can be obtained from the profiles.

(vi) *Spectrographic Studies of Trace Elements in Soils*

Detailed examination has been made of analytical results for samples of soil and parent material from 19 profiles from Queensland and 18 from central Australia, both lots formed from a variety of parent materials, and of 17 profiles formed from dolerite in Tasmania. The trace elements were cobalt, copper, manganese, molybdenum, nickel, zinc, and zirconium. This examination has shown that the relation between the concentration of a trace element in the soil as a whole and its concentration in the parent material is frequently not close enough to enable a satisfactory estimate of the former to be made from the latter. Pedogenic factors other than parent material also play important parts in determining the concentration in the soil. During the weathering processes, changes are produced in the concentration of a trace element with the result that the range of concentrations in the weathered material is much greater than that in the original material. As weathering proceeds, the concentrations tend to form clusters about widely separated points in the overall range. The different clusters appear to be produced by the factors that produce the different soil groups formed from the parent material in question. The final result is that, although there may be only a small range of concentrations in soils of one taxonomic group formed from a given parent material, there may be great differences between the average values for soils of different taxonomic groups formed from the same parent material. Consequently, a reliable estimate of the trace element content of a soil cannot generally be obtained from that of the parent material.

In seeking to elucidate some of the pedological problems associated with a region showing trace element deficiencies, 27 further examples of terra rossa and rendzina profiles from the south-east of South Australia have been analysed for eight trace elements. Using the statistical methods mentioned above, values for an average soil were derived and the deviations of individual soils from these were compared with pecularities of their pedology. The results showed that the trace element content of the soils was related to that of their underlying calcareous material, the latter corresponding with the different geological types of calcareous materials in different areas. Allowance had to be made for incidental volcanic, aeolian, or ground-water influences which were shown by the trace element results. The abundance of the essential elements, relative to a normal soil, were cobalt 1 : 10, copper 1 : 4, manganese 1 : 3, zinc 1 : 2, molybdenum 2 : 1, so that deficiences of cobalt and copper could be attributed to the very low absolute amounts in these soils. The distribution of manganese within the profiles corresponded with that of calcium and organic matter. Manganese was higher in the surface soils of the terra rossa group than in the rendzinas. Increases in clay were associated with only partial increases for some of the trace element concentrations; within the rendzinas, in which clay is more dominant, the association was more noticeable than in the terra rossa group. Copper and zinc showed an opposite tendency to that of clay, tending to decrease with depth.

Twenty soil profiles from the Todd River area, central Australia, have been analysed for cobalt, copper, manganese, molybdenum, and zinc. The concentrations and trace element profiles observed had no special features which could be called characteristic of arid zone soils. However, compared with the results for a recent survey of Queensland soils, the Todd River soils had, on the average, a smaller range of concentrations in the profiles. The weighted mean concentrations in the soils were more closely correlated with, and more nearly equal to, the concentrations in the C horizons. This could be due to less severe weathering and leaching in the Todd River soils, leading to slower movement of trace elements from one horizon to another, and smaller losses in the drainage water.

(vii) *Atmospheric Chemistry*

Work continued on the analyses of rainwater from Merbein, Alice Springs, and Katherine. Results obtained for Merbein in the dry winter of 1959 will probably help in the elucidation of the widely varying composition of the dissolved material at that centre. From work in cooperation with officers of the Division of Land Research and Regional Survey with regard to samples collected at Katherine, the pattern of the salt distribution there has become apparent. The rainwater from some of the showers at Katherine was so free from dissolved material that it was difficult to differentiate between it and laboratory distilled water.

At the request of the Institute of Meteorology, Stockholm, Sweden, rainwater from a number of centres in Australia is being collected as part of a world-wide survey of rainwater for tritium. The analyses will be carried out in Stockholm.

(viii) *Miscellaneous*

Tabulation was completed of the environmental, morphological, and chemical data for three representative profiles of each of the great soil groups represented in Australia. These quantitative data are intended to supplement the descriptive information included in "A Manual of Australian Soils" previously published by the Division.

A punched card index has been compiled so that all trace element analyses carried out in the laboratories of the Divisions or published from other parts of Australia may be related to amount in the soil, great soil group, parent material, or location. The value of this index will increase as more results accumulate.

In association with the Soil Physics Section the bonding of polyvinyl alcohol to montmorillonite has been studied by measuring swelling properties and viscosity after the addition of sodium chloride. The study disclosed that a regular series of hydrogen bonds is formed.

Comments about the poor conditions of many turf cricket pitches in the Adelaide metropolitan area led to a small survey to assess the salinity problem. In many cases it was found that the salt content was more than 1% and the grass was dead. In a few cases, where watering had been carried out much more heavily, growth of grass was satisfactory and the salt content was closer to 0.1%. An experiment at one oval showed that grass could be satisfactorily re-established by ponding water over the pitch for several days and following this with liberal applications of further water. The main factors leading to the build-up of salinity to levels which were toxic to couch grass appear to be the normal moderate salinity of Adelaide reticulated water, the lack of winter rains in 1959, and continued failure to use sufficient water in the preparation of wickets on the heavy soil.

Detailed fractionations have been made of a number of sand samples, together with microscopic examination of the grains, in an attempt to identify the source of the sand material in some soils. So far the information has been negative for soils from the south-east of South Australia but some useful leads were obtained from sands from the MacDonnell Ranges.

Interest has continued in the improvement of laboratory and field methods for the examination of soils. During the year colour charts were produced to facilitate the field use of the improved colorimetric method for the determination of pH in soils, described in the last annual report. Arrangements were completed with a private firm for the commercial production of these charts and an indicator kit.

Further refinements in flame photometry have confirmed the error caused by magnesium in the determination of calcium in ammonium chloride extracts. Magnesium enhances the intensity of the calcium radiation.

The determination of the very small amounts of phosphorus that occur in Australian soils, particularly in the presence of so much iron as is frequently found, has always been difficult. Work in Perth and Adelaide has been coordinated and modifications made to the ascorbic acid method of reduction have yielded a simple and precise method for the determination of phosphorus in soils.

In conjunction with the Instrument Workshop and other Sections, a portable hand-operated core sampler has been developed which facilitates the taking of 2 in. soil cores for analysis. The main features are the use of a thin soil tube, sufficiently thin so as to avoid undue compression of the soil, and the 3% relief of diameter, both inside and outside at the sharpened end of the tube. The tube is driven into the soil by means of a sliding weight which drops on to an anvil fitting closely over the upper end of the sampling tube. The tube is given a thin coating of mould oil before driving it into the soil. Core samples up to 42 in. in length may be taken by two persons in as little as 20 min. At depths below 2 ft the sampler can be withdrawn by hand, but from greater depths a hydraulic jack is used.

4. Soil Physics

This section of the report of the Division of Soils deals with research in soil physics undertaken by staff stationed at the headquarters of the Division in Adelaide. Further research in soil physics undertaken by the Division of Soils in other regions of the Commonwealth is described later in this chapter.

(i) *Soil Moisture and Water Balance of the South-east of South Australia and South-west of Victoria*

Following conclusion of work done in cooperation with the Department of Mines, South Australia, on the hydrology of portion of the Upper South-east, investigation has commenced of the shallow ground-water of the Gambier sunklands. Four steel lysimeter tanks have been installed near Mount Gambier. Two tanks are 6 ft 6 in. by 8 ft deep and two are 6 ft deep. They have been refilled with the local soil and work is proceeding to equip the tanks to measure the drainage of soil water to the local water-table. The 8 ft deep tanks will probably penetrate the local water-table for most of the year. The tanks will not be weighed, but the change in soil moisture storage of the tanks will be estimated from neutron moisture meter readings, water-table measurements, and tensiometer measurements near the soil surface.

The hydrology of the Gambier sunklands is determined very largely by the Tertiary limestone deposits which have a high permeability to water. This unconfined and shallow aquifer conducts away to the sea much water which would otherwise appear as creeks and rivers in this locality of relatively abundant rainfall. The aim of this new project is to measure the amount of water draining through the soil profile to the water-table, the evapotranspiration from the land surface, and the annual discharge of water through the shallow aquifer.

(ii) *Drainage and Soil Moisture Regime on Irrigated Swamps of the River Murray*

Together with officers of the Department of Agriculture, South Australia, measurement started on the water balance of the reclaimed swamps of the River Murray, which are used for irrigated pastures. Long Flat Swamp, near Murray

Bridge, was chosen as being representative of the swamps. The hydraulic conductivity of the soil on Long Flat has been measured at sites along three transects from the river to the high land, to a depth of 2 metres. Access tubes for the neutron moisture meter have been installed, and water-table levels are being observed in bore holes. The work will be developd to measure the water balance of the irrigated swamps and the soil moisture regime in the root zone of the pastures.

(iii) *Soil Moisture Conditions at the Second Valley Pine Forest*

Investigation of the seasonal soil moisture regime at the Second Valley pine forest continued. The year 1959 was extremely dry, and the results so far should represent conditions of drought rarely experienced at Second Valley. If 1960 proves to be wetter than normal, as it promises, the two years will represent extremes of the soil moisture regime, within which more normal seasons may be interpolated. Three sites representative of the soils and landscape positions were chosen, viz. ridge top possessing a well-developed lateritic soil, middle slope possessing a truncated and degrading lateritic soil, and the valley bottom possessing a podzolized soil formed on mica schist parent material. The Woods and Forests Department, South Australia, have evidence that the growth of *Pinus radiata* improves with lower elevations in the landscape.

The soil moisture investigation embraces measurement of the amount of water capable of being stored in the soil profiles and used by the pines during drought periods, and the rate of supply of soil water in response to water deficit. In addition, during a wet winter, it is already clear that a perched water-table establishes itself on the rather impermeable ridge-top soils, and the aeration of the root zone of these soils must be very unfavourable for growth. The investigation should also add some quantitative data to the description of lateritic soils, by measurement of permeability to water and the mode of dissipation of the perched water-table.

(iv) *Evaporation from Bare Fallowed Soils, in the Field*

Work with a wind tunnel, into which small pots of soil were placed, showed that the structure of the surface of the soil determined the rate at which water was evaporated from the soil surface. The soil with a fine tilth of structural size $\sim$ 2.5 mm dried more slowly than soils with a cloddy structure or a flat untilled surface. This investigation was continued in the field to determine whether the results of the wind tunnel could be duplicated under natural meteorological conditions. Four plots on a red-brown earth soil were used, from which all weeds were removed by hoeing and hand-picking. One plot was left untilled, the second was worked to a fine tilth, the third was chisel ploughed, and left in a very coarse cloddy condition, and the fourth was covered with a black plastic sheet as a mulch. The evaporation from each was determined by soil sampling, both directly and with the neutron moisture meter.

The plastic covered plot lost very little water. The fine tilth plot lost more, but less than the other two plots, which were similar to each other. These results therefore repeated the observations made in the wind tunnel. The experiment is being extended particularly with respect to study of the depth and suction characteristics of the dry mulch zone at the soil surface.

(v) *Permeability of Soils to Water*

Further refinements of the gamma ray method of measuring distribution of water content in soil columns have improved its accuracy. As a result, determinations of rate of water movement in the column can be made for non-steady-state flow, and in conjunction with a null-point balancing system for tensiometers, soil-water suctions may be measured rapidly. Unsaturated permeabilities may be determined far more quickly therefore than in the steady-state flow system used previously. Results obtained are being used to examine the usefulness of an equation that has been developed relating permeability to size distribution of pores. The present method enables water content and suction to be determined while water is passing through the system and so provides on one sample all the data required for comparison of measured and calculated permeability.

(vi) *Study of Water Movement in Soils*

An attempt is being made to solve the equations of water flow in a drainage problem taking into account the flow in the unsaturated soil. This gives rise to non-linear equations which can be solved only approximately by numerical work, which must be repeated for each soil type and each idealized drainage configuration. It is intended to check the usual assumption that the water flow is vertical above the water-table.

A variable resistance analogue computer has been made to solve the same problems as above, and subsequently, to solve problems with a more realistic geometry, such as encountered in work on the Murray swamps and in the water balance of the Lower South-east of South Australia.

(vii) *Control of Soil Fertility by Tillage*

The officer concerned with soil work relating to tillage is overseas enquiring into latest developments in this field. Two aspects of the work are being developed in addition to the one reported above on controlling the rate of loss of water by tillage. These concern the strength of soil aggregates and the opening up of inaccessible sites by breaking of aggregates as in tillage. New apparatus has been set up for studying the rate of oxidation of organic matter following the opening up of inaccessible sites.

(viii) *Stabilization of Clay with Polymers*

Previous work had shown that small concentrations of a wide range of polymers can prevent the dispersion of sodium clays in water. This investigation has been extended to calcium clays and calcium montmorillonite, in particular. Using polymers containing only one type of reactive group on each repeating unit, it has been found that the complexes formed may be divided, by simple tests, into three classes. Each class corresponds to a particular mode of interaction of the polymer with the clay, namely, precipitation by the exchangeable calcium ions, chelation by these ions, or hydrogen bonding to the clay surfaces. From corresponding tests on soil crumbs, humic acid is in the first group, and the polymeric fraction of the soil organic matter responsible for the aggregation of clay in soils is in the third group.

To learn more concerning the linkage of hydrogen bonded polymers, detailed work has been carried out with the Soil Chemistry Section using the simplest of these polymers, polyvinyl alcohol. The results support the hypothesis of hydrogen bonding, but confirmation, in the final analysis, should depend on infrared measurements, to ascertain the bond strengths.

(ix) *The Swelling of Clays*

Measurement of the macroscopic swelling of calcium clays has continued. The reduction in the double layer swelling of calcium montmorillonite in dilute calcium chloride solutions has been particularly helpful in elucidating the mechanism of polymer-clay interaction discussed above.

(x) *Sealing of Earth Dams*

The testing of soils from proposed, or leaking, dam sites has been continued in close cooperation with the Department of Agriculture, South Australia. A total of 15 proposed sites and 13 leaking dams were examined. This work, in addition to the previous year's, has enabled a general correlation to be made between soil type and its suitability for dam construction. Excluding gravel seams and soils containing too little clay, for a dam to be successful in holding water, the aggregated clay in the soil crumbs must be partially dispersed by mechanical or chemical means. The particular treatment depends on the physical chemistry of the soil and its clay mineral composition. The only dams, for which there is no remedial treatment at present, are those in soils containing appreciable quantities of gypsum. Here, some completely new technique is required.

Heavy opening winter rains, following a very dry summer, have caused blow-holes in certain dams. This is due to too high a percentage of sodium ions on the exchange complex. A field experiment is in progress to check various possible treatments. Present indications are that the best result will be achieved by the addition of a small quantity of ferrous sulphate.

The problem of salt water storage has been investigated for the Electricity Trust of South Australia. Here the solution is to compact the soil while it has its own natural moisture and salt content, and only then to pump in the salt water.

(xi) *Stabilizing Sand*

Work has been undertaken for the South Australian Harbours Board to find the most economical means of protecting areas of dune sands, levelled during the summer months, against subsequent wind erosion. It was easily shown that if the surface of the sand could be aggregated stably against break-up by rainfall, then wind erosion could be avoided. To achieve this, a series of boxes were filled with sand and the surface 3 mm of sand treated with either starch, sodium silicate + gypsum, plaster of paris, or a bitumen emulsion in water. The boxes were then exposed to the elements for three months. A successful treatment held the sand together and yet allowed the rain to percolate through. The cheapest satisfactory material was found to be the asphalt emulsion. Cement was also investigated, but the high summer evaporations did not allow sufficient time for setting. Bitumen is being tried at present on a field scale, together with undersown ryegrass, which, when it germinates in the following autumn, will assist in stabilizing the sand.

(xii) *Routine Physical Measurements*

New suction-plate and pressure-membrane equipment were brought into service during the year. However, the demand for routine physical measurements has declined compared to previous years, as regional stations and other organizations have acquired their own equipment. With more equipment available and no back log of samples, results can now be supplied more promptly than before.

5. Soil Microbiology

This section of the report of the Division of Soils details research on soil microbiology undertaken by staff stationed at the headquarters of the Division in Adelaide. Further soil microbiology research undertaken by the Division of Soils in other regions of the Commonwealth is described later in this chapter.

The Soil Microbiology Section of the Division uses microbiological and biochemical techniques to study problems in soil fertility and pedogenesis. Fertility investigations include interactions between rhizobia and legumes, between mycorrhiza and pines, or between rhizosphere organisms and their host plants, decomposition of organic matter and minerals, and release of plant nutrients by microorganisms. As a contribution to pedogenesis the chemical nature of humus from various soil types is being compared. Recently work commenced on petroleum prospecting by determining the numbers of hydrocarbon-oxidizing microorganisms in the subsoil.

(i) Rhizobium–*Legume Studies*

(1) Rhizobium.—Studies have continued on patterns of dissociation of smooth and non-smooth colonies of *Rhizobium*. Observation of colonies by oblique light, staining with crystal violet, and use of 2,3,5-triphenyltetrazolium chloride in media have shown that heterogeneity is common in most isolates carried as laboratory strains. Some degree of control of smooth to non-smooth dissociation has been obtained by variation of cultural conditions, when it has been found that media supplements such as yeast extract, sauerkraut juice, peptones, and casamino acids have enhanced the preponderance of non-smooth dissociants, as do extremes of pH and lengthening the period of incubation between subcultures. By appropriate manipulation of growing conditions it can be shown that most rhizobia will produce non-smooth dissociants, and in this condition will frequently form endospores.

Growth factor requirements of a number of strains within the various species of *Rhizobium* have been examined to ascertain the importance of B-group vitamins in root exudates as a factor in the establishment of rhizobia in the rhizosphere after artificial inoculation. Almost all strains synthesize sufficient of these vitamins to enable some growth to be made, and only under rigorously controlled conditions can deficiency be shown. On the other hand, most strains show little response to added vitamin mixtures, but marked responses can be found to yeast extract and sauerkraut juice, and small responses can be found to root exudate. The responses to yeast extract and sauerkraut juice are not related to their B-vitamin content, but some other as yet undetermined factors must be important.

A number of strains of rhizobia have been screened for their sensitivity to a range of antibiotics. In general, most strains are extremely resistant to penicillin and sulphafurazole, but sensitivity to a range of six other antibiotics showed various spectra of response, with generally strong susceptibility to streptomycin and erythromycin, but often with secondary growth of resistant colonies as small papillae. It has not been possible to utilize the data as a taxonomic aid.

(2) *Toxic Seed Substances*.—Seeds of both *Centrosema pubescens* and *Trifolium subterraneum* contain substances toxic to their appropriate rhizobia and to a number of rhizosphere organisms. These substances are more toxic when tested on agar than in sterile sand or soil. They are stable to autoclaving.

(ii) *Mycorrhiza–Pine Studies*

(1) *Isolation of Mycorrhizal Fungi*.—Numerous pure cultures have been isolated from fruiting bodies of basidiomycetes found in plantations of *Pinus radiata*, from mycorrhizal roots after prolonged washing to remove most contaminants, from needle litter, and from soil. A technique has been perfected for testing the ability of these isolates to form mycorrhizas on the roots of pine seedlings grown aseptically in Leonard jars. The most efficient mycorrhizal fungi will be selected for testing in nurseries and in plantations.

(2) *Root Profile Studies*.—The poor growth of *Pinus radiata* on lateritic soils in South Australia and Western Australia is being investigated. Root profile studies showed that the poorest trees have the poorest root development, judged by the density of roots down the profile and the spread laterally. Well-grown pines showed maximum root development within the first foot of soil, gradually tailing off to a depth of 5 ft in well-drained gravelly laterite. Only a few thick roots penetrated the impervious B horizon, mainly along cracks. Mycorrhiza development was not well correlated with tree health since some of the poorest pines possessed good mycorrhiza, at least in the surface soil; but the best trees always possessed an abundance of roots infected with mycorrhiza, often down to a depth of 5 ft. It was difficult to say whether high water-table in winter and low soil temperature restricted root and mycorrhiza development more so than dry conditions in summer and high surface soil temperatures. These variables can be separated only by controlled studies of pure growth in large pots with varying levels of moisture and at different temperatures.

(iii) *Rhizosphere Microorganisms — Plant Root Studies*

(1) *Root Exudate Studies*.—Study on the exudation of several B-vitamins from plant roots was extended to 10 plant species grown under a range of environmental conditions. Biotin was consistently present in exudates in amounts sufficient to influence the growth of rhizosphere microorganisms. Pantothenate and niacin were generally present, but usually at low levels unlikely to influence the microflora, riboflavin and thiamine were occasionally found in traces, and pyridozine was not detected in any root exudate.

The vitamin content of the exudate varied with plant species. Field pea released large quantities of biotin, pantothenate, and niacin, but the other plants, including legumes, produced exudates medium to low in vitamin content and varying in relative amounts of each. A comparison of five species of clover showed distinct differences in patterns of exudation closely related to plant species and not seed size. Variation of temperature, light intensity, and nutrition resulted in only small differences in exudation patterns, pantothenate being the exception in that more was exuded under unfavourable conditions for plant growth.

(2) *Microorganisms and Plant Root Development*.—The development of roots and root hairs of several plant species was found to be affected by soil microorganisms. In the presence of organisms root elongation rates and root hair growth were reduced in comparison with the root systems of the sterile control plants.

The root stunting effects were observed with radiata pine, phalaris, subterranean clover, and tomato growing in sand and agar, whilst the root hair suppressing effect was most noticeable with subterranean clover. There are indications that each phenomenon is caused by different microorganisms and, although they could be produced with inocula from various soils, the severity of the effects often varied with the inoculum. The degree of root stunting was also affected by environment, being greatest when the plants were grown at low light intensity.

(3) *Identification of Rhizosphere Bacteria*.—When a number of rhizosphere bacteria, previously designated as arthrobacter-like nocardias, were compared with type cultures of *Arthrobacter globiformis* and *Nocardia asteroides* they were found to be quite different. Sneath's suggested method of classification, based on correlated characters, was used on 43 selected isolates together with four type and 17 named cultures. Based on 31 characteristics, these unknown organisms fell into five groups with the known cultures of *Arthrobacter* spread over three of these five groups. *Nocardia* and *Pseudomonas* cultures were similarly scattered over several groups, thus rendering this method of classification invalid. Most of these irregularities were obviated by identifying the isolates with the help of Skerman's key.

(iv) *Solubilization of Phosphate by Microorganisms*

"Sulphur-phosphate" granules were prepared by mixing 1 part of sulphur powder with 5 parts of ground rock phosphate. A number of sulphur-oxidizing bacteria were obtained which could oxidize the sulphur. In laboratory studies *Thiobacillus thiooxidans* and *Thiobacillus concretivorus* rapidly oxidized the sulphur to sulphuric acid which in turn dissolved much of the rock phosphate. *Thiobacillus neopolitanus* was much less efficient, probably because it was unable to withstand very low pH. The fluorine in rock phosphate did not inhibit the thiobacillus. In glass-house experiments with two plant species (lupin and subterranean clover), two soils (a podzolized sand and a red-brown earth loam), at two pH values (pH 6.5 and 4.8), were treated with "sulphur-phosphate", rock phosphate, and superphosphate at two levels (phosphorus equivalent to 2 and 4 cwt of superphosphate). In general superphosphate was slightly superior to "sulphur-phosphate" and rock phosphate, which were in turn about equal. Yields were greater at pH 6.5 than at pH 4.8 for both plants. No explanation can be given for the surprisingly good result from rock phosphate alone. This trial will be repeated this year.

Field results with subterranean clover in 1959 on a podzolized sand were adversely affected by the drought; but superphosphate was better than "sulphur-phosphate" which was better than rock phosphate. This trial will be repeated this year on a deep sand where soluble phosphates tend to leach rapidly and on a laterite where phosphates are avidly fixed.

(v) *Humus Studies*

(1) *Identification of Phenols and Organic Acids from Humus.*—Humic acid from a number of soils was decomposed by acid and alkaline hydrolysis, by oxidative and reductive degradation, by zinc distillation, and by potassium hydroxide fusion, all at high temperatures. The fragments were separated by chromatography and tested for phenols and organic acids in the hope they might reveal the nature of the building blocks for humic acid. Four to six phenolic spots and two to three organic acid spots were found after fusion with potassium hydroxide, but very few spots from any other treatment. Complete identification of any spot has not yet been achieved because of the small amounts available for study.

(2) *Red Pigment from Green Soil.*—A similar green soil to that previously reported from Kangaroo Island has been found in Tasmania. An identical red pigment has been extracted from each green soil with absorption peaks at 245, 390, and 550 mμ. The purified pigment contains about 75% carbon, 10% hydrogen, and 15% oxygen, and has a molecular weight of approximately 400. There is one methoxyl, three methyl, no acetyl, and no carboxyl groups per molecule, but one or two carboxyl groups appear after saponification. There are no aliphatic double bonds. Infrared analysis shows the presence of ketonic ($C = O$), ester ($CO - OR$), and aliphatic ($-CH_2-$) groups, but no hydroxyl (OH) and only slight aromatic nature. Alkaline hydrolysis products smell like menthol, rather suggesting a terpene-like structure. Despite numerous tests no plant or micro-organism has been found growing on the green soil with a similar red pigment.

(3) *Decomposition of Aromatic Nitrogenous Compounds.*—Investigations have commenced on the bacterial decomposition of aromatic nitrogenous compounds, particularly those derivatives in which the nitrogen atom of an amino acid is linked directly to a carbon atom of the aromatic ring. These studies were prompted by work on the structure of humic acid which it is believed may consist in part of polymers formed from the condensation of quinones with amino acids. Bacteria which have been isolated from soil enrichment cultures can grow on media consisting of agar, mineral salts, and either *N*-phenylglycine, *O*-carboxylic acid, *P*-nitrophenylglycine, *P*-nitrobenzoic acid, or *P*-nitrophenol as sole sources of carbon and energy. These substrates were added to the medium in low concentrations (0.01–0.05%) so as to minimize their toxic effects; consequently bacterial growth was never profuse. *N*-phenylglycine and 2,4-dinitrophenylglycine failed to support growth when added as the sole carbon source. The mechanism of breakdown of

these compounds and the effect of various substituents in the aromatic ring on their susceptibility to attack will be studied in detail.

(4) *Soil Respiration Studies.*—The oxygen uptake of a wide range of soils from south-eastern Australia was measured with the Warburg respirometer and the effect of drying and wetting cycles on soil metabolism studied. In all instances wetting a soil after a period of air dryness resulted in an immediate respiration greater than that of a soil maintained in the moist state. This high rate of respiration following re-wetting declines after 6–12 hr and within 24 hr was similar to the continually wet soil. The stimulation in oxygen uptake with drying and wetting varied with the soil type.

(vi) *Soil Structure Studies*

Examination of a wide range of sandy soils showed that sand grains were frequently bound together with filamentous hyphae of fungal or algal origin. In soils of heavier texture similar threads were found as reinforcement in soil aggregates, and these undoubtedly contribute to aggregate strength. Study was undertaken to isolate organisms from soil which produced such threads. A large number of fungi and actinomycetes were isolated and inoculated back into sterilized soil, thereby producing a degree of aggregation proportional to the amount of growth, but the morphology of these filaments is not identical with those contributing the greatest amount of aggregation of field soils. The search is being extended therefore to water-moulds and blue-green algae to see if they are the likely sources of the observed filaments.

6. Mineralogy

This part of the report of the Division of Soils describes the work of the Mineralogy Section, which is stationed in Adelaide.

(1) *Structure of the Micas.*—The study of the dimensional misfit between the several layers of the mica structures has been extended. As a result a new "ideal" mica structure has been proposed in which the interlayer cation plays a more dominant role than previously. This leads to general formulae for predicting the amount of rotation suffered by the silica tetrahedra, and for giving some indication of the separation of successive layers across the interlayer region in structures not yet determined accurately. The same formulae allow reasonable guesses to be made about possible departure from the ideal value of the tetrahedral angles in various micas.

A careful consideration of the symmetries of the micas suggests that the three octahedral positions are not equivalent, and that these cations may well be ordered in tri-octahedral micas. This may also be the reason for the restricted composition range for muscovites, and suggests a mechanism for the structural control of polymorphism in the muscovite-lepidolite range.

Previous workers have assumed that successive layers in mica polymorphs may be freely rotated relative to each other, so that the octahedral cations are unlikely to provide a structural control of polymorphism. The new "ideal" structure may allow these cations a more positive control of polymorphism.

The formula for calculating the rotation of the silica tetrahedra apply to all layer lattice silicates, and it has therefore been possible to check this by comparison with observed rotations for several structures known with sufficient precision. Previous formulae for calculating the unit cell dimensions of layer lattice silicates have been shown to break down markedly for certain micas. A more rational basis for such formulae can now be presented, taking into consideration the new "ideal" mica structure proposed. The new formulae — which require separate constants for each mineral group — provide more satisfactory agreement with the most accurate unit cell data available on carefully analysed specimens.

(2) *Phosphate Minerals in Soils.*—Following the isolation and identification of gorceixite and related minerals in various soils, as detailed in previous reports, investigation is continuing into the geochemistry and mineralogy of these phosphates. Most of the evidence available suggests that the minerals are formed in the soil and are not simply resistant residues of the soil parent materials. However, as this question is important, a detailed study is being made on some soils to obtain more positive evidence either way. A podzolic soil containing gorceixite, from South Australia, has been sampled in great detail involving hundreds of samples, and detailed mineralogical and chemical data are being obtained to determine the distribution of the phosphate mineral in relation to features such as local topography, depth in profile, and parent material.

In certain basaltic soils high in phosphorus, gorceixite, although present, is not of sufficient abundance to account for the total phosphorus content. In these soils attempts are being made to concentrate and identify any other phosphate minerals present. The work entails elaborate chemical, mechanical, magnetic, and specific gravity separations. Although it has been possible to concentrate the phosphorus to relatively high levels ($> 1\%$) in certain separates, no other phosphate mineral has as yet been identified.

(3) *Iron Oxides of Soils.*—By digesting certain soil clays with 5N sodium hydroxide it has been possible to obtain almost pure goethite, pure enough for a detailed chemical and X-ray diffraction study.

The majority of soil goethites have some of their iron replaced by aluminium, some as much as 25%. The replacement decreases the unit cell size and a linear relationship was found between the d_{111} spacing and the percentage molar substitution.

The occurrence of such large amounts of aluminium in goethite accounts for some other anomalies in behaviour. Not all goethites are easily extracted by the conventional "free iron removal treatments" and it is found that the presence of a lot of aluminium lowers their solubility to these reagents. Various free iron removal treatments are specifically designed to dissolve only iron oxides, and yet often soils yield appreciable amounts of aluminium from these treatments. Most of this aluminium is considered to be present in the goethite.

(4) *Swelling Studies.*—To investigate which factors influence swelling, montmorillonites of different origins, having different surface densities of charge

and chemical composition, have been fractionated into particle sizes with equivalent spherical diameters of < 0.05, 0.1–0.05, 0.2–0.1, and 0.5–0.2 μ in a Sharples centrifuge. Oriented clay flakes were prepared after sodium saturation and washing. A low-angle X-ray diffractometer, specially designed for the purpose, was used to record diffraction from the swollen flakes, and determinations of the degree of orientation of the crystals within the flakes were also made.

Similar studies were made using single crystals of lithium vermiculite and butylammonium vermiculite in an attempt to eliminate particle size and orientation from the general problem. Initial studies with vermiculite yielded erratic results, and it was eventually found that more than normal care had to be exercised in saturating the vermiculite or its swelling behaviour would vary.

The diffracted intensities measured with the low-angle diffractometer require correction for several geometric factors, and appropriate mathematical formulae have been developed. The diffractometer has a line source of X-rays which produces a smearing of the pattern, and correction for this is complicated by the fact that the crystals of the specimen are not randomly oriented.

(5) *Pedology Studies.*—In connexion with pedological studies elsewhere in Australia, laterites and red earths from central Australia have been analysed for clay minerals. The clay of the laterites is dominantly kaolin but, like those of many other Australian relic laterites, it contains small amounts of mica and other 2 : 1 layer minerals which would not be expected in a laterite. It is possible that these minerals have always been present in the soil, but the nature of the present environment involving high salinity and other features suggests that the minerals may be forming in this changed regime. The clays of the central Australian red earths resemble most of the more southern soils in that they are dominantly illite and kaolin. The presence of a small amount of hematite accounts for their colour.

X-ray analyses have been made of soils associated with the salt lakes of the Merredin area, Western Australia, and of various other soils from the Queensland, Tasmania, and Canberra regions.

Soils dominant in illite are being used by the Chemistry Section for potassium studies, and to determine the mineral composition of the clays as accurately as possible two X-ray diffraction methods were used. The first method involved powder photography and a comparison of the patterns with standard mixtures, the basal spacings being used for comparison. In the second method the intensities of the 060 lines were measured with a diffractometer and the composition calculated from these. Although the overall agreement between the methods was tolerable, several of the samples gave poor agreement. It is doubtful if more accurate analyses are possible or even significant with such poorly defined minerals as degraded illite.

7. Queensland Region

(*a*) *Soil Survey and Pedology*

The two main surveys — one of the brigalow lands and one in the Central Burnett Valley — were continued, and the field work has now been completed.

Extension of the reconnaissance survey of the brigalow lands to their southern limit in northern New South Wales has resulted in the mapping of important occurrences in the Narrabri–Wee Waa district, the North Star–Moree area, west of the Culgoa River, and north-east of Bourke where it extends 20 miles north across the border. However, their aggregate area compared to Queensland occurrences is relatively small. In general, the soils of these areas are similar to those mapped previously, three of the four Queensland groups being represented.

Soils of the western occurrences are particularly interesting and their association with brigalow is curious in that, unlike all other areas mapped, they are light textured. Red sandy loam surface horizons grade with depth through clay loams and light clays into highly calcareous medium clays within 2–4 ft of the surface. In morphology they resemble soils derived from parna in the Swan Hill area, Vic. It is considered likely that their parent materials are of aeolian origin. The associated brigalow is a tall-growing form with which little suckering occurs. By contrast a stunted form of brigalow which suckers freely is found on adjacent heavy clays.

In the Central Burnett region, the reconnaissance survey has been extended to include the Mundubbera 1-mile sheet, and now covers a rectangular block of 1050 sq. miles lying across the strike of the major geological formations. Wide ranges of parent materials and soils are represented. The survey has focused attention on a number of soils not covered by recognized Australian soil groups, and on differences of morphology and fertility between soils under grassy eucalypt forests and those under dense softwood scrub vegetation. The high macroporosity of the latter is striking and is undoubtedly an important factor in their reputed high productivity. A group of soils has been recognized associated mainly with softwood vegetation and characterized by gradational texture changes, a firm heavy clay subsoil, and high macroporosity with worm activity in the upper part of the solum.

During field work and laboratory investigation of the soils the main emphasis has been on aspects of land use and comparisons of soils of medium to high productive potential. The officer responsible for the work has now been granted leave for overseas study and the survey must be terminated short of the limits originally planned.

At Samford a survey was made of the soils of the 430 acre area recently added to the C.S.I.R.O. Pasture Research Station. Ten units, each dominated by soils of one great soil group, were mapped. Parent materials were identified, and profiles sampled for laboratory analysis to provide a basis for the siting of experiments and interpretation of results.

A provisional soil map of Queensland was compiled as a contribution to the soil map of Australia which is to be presented at the International Soils Congress in the United States this year.

The collection of a series of profile monoliths representing important Queensland soils has been initiated. These will be used for studies of micromorphology and for display and have already attracted much interest from visitors.

(*b*) *Soil Micropedology*

An officer of the Micropedology Section was transferred to the Queensland region during the year. It is proposed that mineralogical and micromorphological studies will be directed mainly towards elucidation of (i) changes that have taken place in the development of major profile forms from specific parent materials, (ii) the influence of pedogenic process, and (iii) degree of development on nutrient reserves present in the form of weatherable primary minerals. Pending the setting-up of full laboratory facilities, an exploratory mineralogical study of a group of clay soils of the brigalow lands has been commenced.

(*c*) *Soil Chemistry*

Studies of extracts of soil organic matter have continued with emphasis on the mineral constituents simultaneously dissolved or entrained. Purification of organic matter in the extracts, by methods similar to those of other workers, gave organic materials which were markedly more organophilic than mineral-contaminated materials. Using these techniques, practically ash-free preparations of organic matter have been isolated from several contrasting soils. Two soils which gave extracts with somewhat higher residual ash were found to contain finely divided anatase. As has already been reported, ash-free organic matter gives titration curves with sharp end-points when titrated against alkali. The reaction of these preparations with copper was analogous to the reaction of certain organic hydroxy acids. The ability of organic matter in some soils avidly to retain copper, and other micronutrient metals, may be due to the presence of hydroxyl and carboxylic acid groups spatially placed so that they can chelate metal ions.

These results contribute to the understanding of micronutrient availability in soils, and several aspects of this are reiterated here. In the first place, it is not necessary to assume that the organic matter of copper-fixing soils is altogether different from that in healthy soils. It seems more likely that the chelating sites in the latter soils are blocked preferentially by iron and aluminium. This is in accord with general experience that the soils which bind copper most avidly are those rich in organic matter in proportion to their clay minerals and sesquioxides. In the pH range of approximately 5–8, soluble sodium organic matter extracted from soils can keep in solution considerable amounts of metals such as copper, iron, and aluminium. The traces of soluble organic matter occurring naturally in many soils may be important in countering retention of metal ions by the insoluble organic fraction, and in ensuring the presence of mobile traces of metals in the soil solution. Competition of metal ions for the non-specific chelate sites in both the soluble and insoluble fractions of organic matter could be the cause of many of the interactions of micronutrient metals reported in plant nutrition studies in soils.

Interest has extended from consideration of the unusual acid montmorillonitic subsoils of the brigalow region to a general consideration of the reactivity of aluminium and silica in soils. There is rather little information on the amounts of readily soluble SiO_2 and aluminium in different soils. Development of specific analytical methods to estimate different chemical combinations of these constituents would be a formidable task if indeed it proved possible. An empirical study has been made of the amounts of aluminium and monomeric silica dissolved during extraction of soils with 0.01 N sulphuric acid as used for the determination of "available" phosphate. Surface soils were chosen representing a number of great soil groups and the mean levels of soluble aluminium and soluble silica calculated for each group. Between every pair of the six great soil groups sampled there was a statistically significant difference in either mean level of soluble silica or mean level of soluble aluminium. Samples from a number of profiles have also been analysed.

Experiments are being conducted on the extraction of aluminium from soils, with buffered solutions of ammonium salts, in an attempt to gain information on the nature of readily soluble aluminium in soils. A modified oxine method for the determination of aluminium has been developed, which is suitable for analysis of soil extracts and is preferred to the more usual methods based on "Aluminon".

Analyses to characterize soil samples collected by officers of the Soil Survey and Pedology Section in this region constitute a considerable proportion of the work of this laboratory. Most samples analysed during the year under review have been collected from the brigalow country and from the Central Burnett area.

(*d*) *Soil Fertility*

(1) *Studies in Phosphate Availability*.—Preliminary studies on the assessment of phosphate status of soils by various techniques were completed during the current year. With the use of 10 soils, which contrasted strongly in morphology and fertilizer treatment, phosphate potential measurements on air-dry soil could be closely correlated with phosphorus uptake by millet in Neubauer pot tests. Phosphate extracted with dilute acid did not provide a sensitive measure of availability to this crop. Larsen values (using ^{32}P) were obtained on three basaltic soils of contrasting profile morphology using three test crops. Results from a black earth and krasnozem suggested that the use of Larsen values is a possible alternative to phosphate potential measurements or Neubauer tests in showing the relative order of available phosphate. A lateritic krasnozem, however, yielded negative Larsen values in some cases, suggesting a high energy of phosphate sorption by this soil. Lettuce and millet showed similar Larsen values on the krasnozem and black earth, whereas lucerne showed a higher Larsen value, suggesting a more efficient utilization of soil phosphate in the labile pool. These experiments will be continued with special reference to the kinetics of equilibration of ^{32}P in soils whose phosphate status has been assessed by other methods.

(2) ^{15}N *Studies*.—An officer of the Section received a short training period on basic techniques in mass spectrometry through the C.S.I.R.O. Division of Chemical Physics in Melbourne. The degree of ^{15}N enrichment employed in one glass-house experiment appeared adequate to permit the interpretation in future experiments now planned, of the nitrogen transformations in both soil and plant components. It was also apparent that the Dumas total nitrogen method, while giving excellent results for nitrogen content, yielded gas samples which showed erratic $^{15}N/^{14}N$ ratios. This may be due to memory effects in the heated cupric oxide column or to displacement of nitrogen gas, of different enrichment, which is dissolved in the alkali in the nitrometer. Studies on the determination of total nitrogen in soil and plant material are proceeding; the conventional Kjeldahl

method recovered 71–95% of the total nitrogen that was obtained by the Dumas method from a wide range of soils. Several published improvements of the Kjeldahl method are now being attempted. A small room to house the new Metropolitan-Vickers MS3 mass spectrometer is practically completed, and delivery of the instrument is expected early in the next financial year.

(3) *Soil Fertility Survey.*—The fertility status of a further group of soils has been assessed. This group represented black earths, krasnozems, and grey and brown soils of heavy texture from the brigalow belt, and solodic soils. Responses to phosphorus were obtained in all cases but one; responses to molybdenum were found in several soils including a black earth. Another black earth showed zinc deficiency. Solodic soils were deficient in several micronutrients.

During a pot trial on a basaltic krasnozem from under rain-forest, it was observed that nodulation of *Phaseolus lathyroides* appeared to be inhibited by the presence of high concentrations of nitrate nitrogen (> 200 p.p.m.). This was confirmed by a subsequent experiment, but lack of nodulation did not appear to affect the accuracy of nutrient deficiency diagnosis.

In collaboration with the Soil Physics Section, the preliminary studies are being finalized on the role of moisture status on growth of indicator plants in pots. A final trial, designed to assess the effect of increasing water content (beyond pF 2) on the growth of lucerne, is now nearing completion.

Further sampling of soils from the plots under *Desmodium uncinatum* at the Beerwah Experiment Station was undertaken. This project has now been expanded to include sampling of virgin soils at Samford Experimental Farm and at the Rodds Bay Station in the spear grass region near Gladstone. The three series of investigations constitute a basic study on the effect of various types of legumes, fertilizer treatment, and location on the build-up of soil fertility (and of soil nitrogen in particular) in the subtropical environment.

(*e*) *Soil Physics*

(1) *Structure Alteration in Cultivated Soils.*—A poor wheat crop was obtained from experimental plots on Mywybilla clay during the 1959 season. There did not appear to be any correlation of crop yield with depth of working, and experience to date has not indicated any significant advantages in this type of culture. The poor yield was partially a result of patchy germination occasioned by planting conditions and the subsequent dry season. The controlling influence of moisture in this area has been demonstrated by the variability of yields obtained in each season with the effect amplified by the conditions of this experiment where continuous cropping has been employed with only a short fallow for moisture conservation. The yield aspects of the experiment have been concluded, although further studies on evaporative loss from the soils are in hand. A pot experiment with the soil packed to various densities to reproduce conditions resulting from different depths of cultivation has been commenced to follow the rate of water loss from the soils. Losses are determined by direct weighing.

An examination of samples from two sites on grassland and a newly cultivated area has been commenced to follow the changes resulting from cultivation on clay soils. There is a rapid loss in water stability of soil aggregates within the first year of cultivation without any marked decrease in organic matter content. Shearing of the aggregates and disturbance of natural packing by implements appear the prime causes of loss in stability. Further sampling is proposed to follow any subsequent changes in soil structure.

(2) *Water Content Changes in Natural Soils.*—Analysis of the observations made in the joint project wtih the Ecology Section, Division of Plant Industry, at Whian Whian State Forest, N.S.W., is continuing. Livingstone atmometers were used as part of the instrumental set-up in this project and an attempt has been made to calibrate these instruments in terms of atmospheric saturation deficit and solar radiation. Although atmometers are subject to some variability in performance, their simplicity and low cost are attractive from the viewpoint of the extensive instrumentation required for ecological work, and when used as an integrating radiometer, they give estimates of radiation which appear as reliable as those obtained from measurement of sunshine hours while allowing much greater flexibility in terms of exposure.

Measurement of water use by different species of *Paspalum* in relation to height of the pasture has continued. Variations in pasture height are provided by the morphological habit of the species and different cutting frequencies. Soil moisture fluctuations are followed with gypsum blocks, but the sensitive range of the blocks in relation to the moisture distribution in the soil concerned has limited the accuracy with which the water use can be computed. Some complementary measurements of leaf areas and stem-leaf ratios are in progress to estimate the effective transpiring surface in each species.

(3) *Miscellaneous.*—A series of determinations has been made on selected soil profiles from the Gayndah area to characterize the porosity relationships of these soils. Work concluded on the physical properties of some soils of the Coastal Lowlands with particular reference to the hardpans of ground-water podzols.

Preliminary measurements of moisture characteristics of soil cores taken by the entomology staff, Veterinary Parasitology Laboratory, Yeerongpilly, have been commenced. These samples were taken from areas where tick control experiments are in progress. Survival of ticks in these areas is very variable, and it is thought that rate of drying of surface soil, heating effects, and density of soil, all contribute to the ability of tick pupae to survive.

The gypsum blocks and associated equipment installed at Goodnight Scrub for the Queensland Forestry Department to assist a study of germination and survival of hoop pine have been recovered. Examination of the observations is still in progress. The germination and early survival of the seedlings were affected by insect attack, so that the plant numbers in each treatment are somewhat limited. Soil cores have been taken for moisture characterization, but preliminary results suggest that soil moisture may not be the predominant effect influencing survival.

Some further experience in the use of an indirect method of establishing equilibrium water contents for pot trials in the glass-house has been obtained. A pot trial is in progress to estimate the effect of different methods of pot watering upon plant yield.

8. South-Eastern Region

Development of edaphic studies has continued, particularly in the subregions centred on Griffith and Armidale. The situation has now been reached where there is a desirable balance between such studies and pedological studies. Also, with the appointment of a senior research chemist, and the anticipated appointment of a research physical chemist, the region now possesses a well-balanced staff in most of the basic disciplines required for soil research. These circumstances will allow the development of a more balanced research program.

(*a*) *Soil Survey and Pedology*

(i) *Canberra*

Soil studies of a proposed extension of the Canberra City area and of the margins of the future Canberra lakes were conducted at the request of the National Capital Development Commission.

A general reconnaissance survey was made of the Southern Tablelands, and in cooperation with the New South Wales Department of Agriculture detailed surveys were made in the Yass Valley in connexion with land capability assessments. The preliminary results of these studies were discussed at a school organized by the Joint Planning Committee of the Yass Valley project.

(ii) *Sydney*

The officer based on Sydney has been engaged primarily on an investigation of an area round Kempsey on the north coast of New South Wales. However, some time has been spent in collaborative soils work on the properties at Badgery's Creek and Cobbity, which belong to the University of Sydney, and on completing work from a previous investigation on the south coast of New South Wales.

The field work for a soil association map of the Kempsey area is nearing completion. Broadly the area consists of: coastal sand country with undifferentiated sands, strongly podzolized sands, and acid peats; the lower Macleay River floodplain with a thin veneer of riverine sediment overlying a deep esturarine clay; hillslope country with strongly differentiated red and yellow podzolic soils; and river terraces with red podzolics and krasnozems on the uppermost terrace, red and yellow podzolics on the next terrace down, cribrisols on the next, and prairie soils on the lowest.

In conjunction with this survey observations have been made on the varying responses to fertilizers in each of the groups of soils. In addition, ground-water and salinity studies have been made. Saline ground-water is close to the surface and is only kept at a reasonable depth by surface accessions of fresh water from river systems and floods. During the dry season, the water-table is lowered with a corresponding increase in salinity. In spite of this there is a considerable reservoir of fresh water at depth in the sands.

A study has been completed of debris-avalanche deposits associated with the talus slopes and the Illawarra scarp on the south coast of New South Wales. This study elucidates the development history of coarse gravelly deposits adjacent to the scarp, and suggests their stratigraphic position in relation to the *K* layers.

(iii) *Armidale*

The work based on Armidale includes: a conventional soil survey of the Dorrigo-Ebor-Tyringham area; edaphic work on the soils of this area and on the C.S.I.R.O. Experiment Farm at Chiswick; and preliminary investigations of soil layering in the Kentucky area.

(1) *Soil Surveys*.—The field work for a broad-scale soil survey of the Dorrigo-Ebor-Tyringham area has been completed. The soils were classified into nine groups on the basis of parent material and easily observed morphological features. At the scale of mapping used only seven mapping units were possible— krasnozem on basalt, chocolate and reddish chocolate soils on basalt, krasnozem on trachyte, red and yellow podzolic soils on palaeozoic sediments, red podzolic soils on granite, red earth on granite, and peat.

Preliminary reconnaissance surveys have also been made of the Walcha-Niangala-Brockendale area and the Boomi-Goondiwindi-Moree-Warialda area.

(2) *Edaphic Studies*.—Edaphic work is being done in collaboration with officers of the Division of Plant Industry stationed at Armidale.

Following the mapping of the soils of the Dorrigo-Ebor-Tyringham area samples were taken from several sites within each soil group and were tested, under glass-house conditions, for nutrient responses. There was a great range of variability between apparently similar soils from different sites. The next stage of this investigation is to determine the variability in nutrient status occurring at one site. A site for this has been selected on the reddish chocolate soils on basalt. Ten samples were taken 4-5 chains apart and each consisting of 10 bulked cores randomly taken over a square chain. These will be tested in the glass-house for response to phosphorus, potassium, sulphur, molybdenum, and calcium, and trace elements as a group. The test plant is white clover.

Oats grown on an area on the C.S.I.R.O. Experiment Farm at "Chiswick" appeared relatively uniform but measurements showed a fivefold variation in yields over the area. Ten sites within this area were selected to give pairs in each of the five yield classes. At each site five soil samples were taken and a detailed profile description made. Analyses of the soil samples are now being made with the aim of correlating yield with soil characteristics.

(3) *Pedological Investigations*.—Preliminary investigations have been made on the nature and distribution of hillside sedimentary layers in granitic country near Kentucky. This study is being developed into a detailed investigation of the occurrence and distribution of soil layering by field observations and appropriate laboratory studies such as sorting, fabric, bulk densities, and mineralogy.

(iv) *Griffith*

Trials are being run to find whether correlations exist between yield of subterranean clover and soil properties. Paired plots on 30 sites giving duplicates on 15 soil types were selected so as to provide as uniform a microclimate as possible. Each plot is 4 ft by 5 ft 6 in. (22 sq. ft), providing a central sampling area of

$4\frac{1}{2}$ sq. ft surrounded by a buffer 15 in. wide. The plots were all given a uniform treatment with regard to cultivation, fertilization, and sowing. Fertilization was aimed at removing suspected deficiencies of phosphorus, sulphur, and nitrogen and, after germination, the plants were thinned so that each plot carried 40 plants per square link. Adequate watering of the plots was provided according to rates predetermined by a pilot experiment and based on evaporation rates. For the initial watering one plot in each pair received water with gypsum dissolved at the concentration of 10 m-equiv. per litre. The subterranean clover crop was harvested at a stage when it was considered that competition for light might affect the rate of further growth. The moisture status of each plot was determined throughout the experiment from small core samples taken from the root zone prior to each irrigation.

The crop has now been harvested and yields are being estimated. Oxygen diffusion rates will be measured on the surface soil and where necessary the subsurface layer. Standard physical and chemical analyses will be carried out on soil from the root zone and immediately beneath it. Detailed soil descriptions have been made.

(*b*) *Soil Chemistry*

Studies on the relation of chemical properties of soils to plant growth and fertilizer requirements have commenced, following the recent appointment of a senior research chemist. Work is being concentrated initially on the phosphate requirements of soils in the New South Wales wheat belt. Field experiments with wheat are being carried out to delineate factors affecting response to fertilizer phosphate under field conditions. Pot trials are planned to measure the effects in contrasting soil types of phosphate sorption on the response of oats to fertilizer phosphate. Related laboratory studies are in progress on the sorption-solution equilibrium of phosphate in soils and pure oxide systems.

(*c*) *Soil Physics*

Routine and special analyses, chiefly particle size analyses, have been carried out in conjunction with field investigation. More detailed analysis of the sand fractions of soils from sand dunes near Swan Hill, Vic., have proved useful in determination of soil history and genesis.

Studies of density, porosity, and macroporosity of aggregates from soils of different *K* layers (different ages) have continued. Macroporosity showed the greatest variation. In layers of different ages formed from similar parent materials (wind-blown) macroporosity of soils containing appreciable amounts of clay decreased with age. More detailed studies of soils from an area where soils were formed, both from layers of colluvium and country rock, have shown that, although age is the main cause of variation in macroporosity, parent material and depth within the layer have some effect.

Density, porosity, and macroporosity measurements have been made on aggregates of basaltic soils in which germination problems occur and which show a rapid decline with cultivation. A very marked and rapid decrease in macroporosity was found to occur with removal of natural vegetation and with cultivation. Tests are being made on aggregate size distribution and capillary conductivity of beds of aggregates after different wetting treatments to assess the effect of cultivation on aggregate size and the effect of resistance to wetting on water availability and conduction.

As part of the edaphic research program, physical measurements are being carried out on subterranean clover plots at Griffith. Exploratory measurements of air space porosity have been made on three consecutive days after watering. The next stage of the experiment involves determination of aeration status by measurement of the rate of oxygen diffusion into the soil from a stirred reservoir placed on the top of a cylinder driven into the soil. A theoretical analysis has been made by the Division of Plant Industry of one-dimensional diffusion in the soil contained by the cylinder. This has shown that with correct design a diffusion coefficient for the soil can be determined in a very short period — about 30 sec to 1 min. Thus the effect of possible temperature changes at the soil surface is minimized. Apparatus has been designed accordingly.

(*d*) *Micropedology*

The study of the occurrence of parna in a restricted watershed near Henty, N.S.W., has been completed and is being compiled. With the transfer of the officer responsible for this work to the Queensland region, further work of this nature has been suspended and mineralogical work has been confined to a few service investigations of the petrography of parent rocks and mineralogy of soil materials.

Investigation continued of the occurrence of quartz and feldspar which is coated with red iron oxide (wustenquarz) in the soils of the Riverine Plain. There is a positive correlation of the percentage of wustenquarz with the occurrence of parna. However, wustenquarz apparently can occur in significant amounts in some riverine materials, and insufficient data are available as yet to fix a percentage above which it can be stated with confidence that parna does occur. Some of the intermediate values in riverine materials may indicate contamination by parna.

(1) *Fabric Studies*.—The descriptive system for soil materials dealing with structure and fabric has been further developed to the stage of publication. A preliminary schedule for description of structure and fabric in the field has been prepared and circulated to a number of field pedologists to test its practical usefulness.

Study of the effects of drainage on fabric in a series of profiles of similar age covering a range of drainage status is continuing. Stereomicroscopic and petrological microscopic studies of the surfaces of voids in some of these profiles have shown that poorly drained, fine-textured soil materials often develop numerous stress cutans, which are difficult to distinguish from clay skins (depositional cutans) in hand specimens.

Attention has been given to the classification of pedological features other than cutans. A tentative morphological classification at a high level of all the pedological features which have been observed has been drawn up. Additional data are required before this can be considered satisfactory.

The degree of development of various fabric phenomena, such as wustenquarz, stress cutans, and depositional cutans, has been plotted against depth for two red-brown earth profiles from the Riverine Plain of New South Wales, to produce profile diagrams of the phenomena. These diagrams show that, in the main, changes in fabric agree with depositional layer (*K* layer) boundaries as assessed in the field.

(2) *Weathering and Soil Genesis.*—After preliminary investigation of three profiles formed on granodiorite from northern Queensland, the red-brown earth occurring in the 25 in. rainfall belt was selected for detailed mineralogical study with a view to making calculations concerning soil formation. The calculations will be based on zircon as the stable mineral. Mineral grain counts on the fine sands of all the horizons have been made, and results so far indicate that the profile has developed from a reasonably uniform parent material. This is a prerequisite to making calculations on soil formation.

9. Tasmanian Region

No new units of the regional survey have been completed this year but work has continued in northern Tasmania and the Midlands. Preliminary work in the field has been undertaken prior to a soil survey of the Beaconsfield municipality. This will extend the work in the Launceston Basin down the western side of the Tamar Valley to the coast where development is rapidly taking place. Because of the immediate need for information about soil character and distribution here, the work on the Ouse sheet has been temporarily suspended so that the West Tamar survey can make rapid progress. Other investigations this year have included a small survey of lands proposed for closer settlement in north-eastern Tasmania adjacent to the Waterhouse area previously surveyed. Assistance has been given to agronomists of the Department of Agriculture locating sites suitable for field experiments on specific soils and including War Service Land Settlement areas on Flinders Island where the area has been covered previously by Divisional soil surveys.

In the laboratory examination of soil samples from the surveys has continued, and a report bringing together all the chemical data on samples from the Launceston Basin area is in preparation. The potassium investigations in the Fingal district have been written up for publication. It is proposed now to extend this work, at first to similar soils and later to other soils of different potassium status. In all cases the soils chosen will be those of which the distribution is known from soil surveys.

The cobalt investigations have been continued. One promising lead is the finding that when cobalt was applied to a podzolic soil and two krasnozem soils, the uptake of cobalt by subterranean clover, white clover, and ryegrass was increased in all cases above that from the control pots, but the increase was much greater with the podzolic soil than with the krasnozems.

On the basis of preliminary experience last year, three soil series known from soil surveys to be of considerable extent and agricultural importance in northern

Tasmania have been selected for further study, this year in cooperation with the Tasmanian Department of Agriculture. Two properties representing the Burnie soil series, one the Brickendon soil series and another the Cressy soil series, have been chosen and sets of soil samples taken from them. On these and on samples of the same soil series from other properties in the districts concerned, subterranean clover is being grown in pots in the glass-house for determination of its cobalt uptake. Concurrently on the four properties the Department of Agriculture will conduct trials to compare the growth rates, and cobalt and copper status, of sheep or cattle receiving cobalt and copper supplements, with those of a control group. From this work it is hoped that a coordinated picture of cobalt in soil, plant, and animal will emerge.

10. Western Australian Region

(*a*) *Soil Survey and Pedology*

At Merredin general field work relating to the genesis and distribution of the soils of an area typical of a large part of the outer wheat belt is now completed. An important finding in this study is the identification of a number of buried soil layers extending from the sides to the floors of wheat-belt valleys. These are believed to act as aquifers carrying water from the catchment areas, leading to the rise of salt water-tables in the valley floors. This aspect is now being further investigated at Korbel, where a valley carrying formerly first-class wheat soils has become saline over the last 40 years. In earlier exploratory work by the Western Australian Department of Agriculture saline ground-waters were found at 8–14 ft, and once these are tapped water rises to within 3–5 ft of the surface. These findings have been confirmed, and it has been further observed that the water is confined between layers of massive, acid clays. The aquifer consists of a similar acid clay, which is, however, much better structured than the materials above or below. In the main salt lake channels the aquifers are cut, or very near to the surface, so that the deposits there are continually wet.

An investigation has been commenced of the soils of the Dandaragan Plateau to the west of Moora and Mogumber to study the light lands of the area. These are predominantly lateritic in origin, and this, together with variations in the Jurassic and Cretaceous rocks forming their parent materials, are the main factors controlling the distribution of the soils.

At the request of the Western Australian Public Works Department, the soils of 400,000 acres of the flood-plain of the Fitzroy River at Liveringa Station in the West Kimberleys were examined in relation to their potential for rice growing under irrigation. The distribution, and chemical and physical properties of the soils were found to be related to an age sequence of ground surfaces occurring both as surface exposures and buried layers. The younger and more promising soils have buried the older soils near to the present-day river courses, while the latter come to the surface towards the periphery of the flood-plain. Camballin clay, the dominant soil of the plain at Liveringa, appears to be comparable with Cunnumurra clay of the Kimberley Research Station, a soil on which rice, sugar cane, and other crops have proved successful with irrigation.

A joint investigation with the Division of Plant Industry of the plant-soil relationships of perennial grasses in the Kojonup area has been commenced. Previous investigations have yielded some information on the soils and their distribution in the Kojonup district, and some understanding has already been obtained of the soil characteristics influencing the growth of perennial grasses in that environment. In this experiment a comprehensive examination of the effects of soil characteristics on the growth of two perennial grasses (phalaris and veldt grass) is being attempted. In addition, the factors controlling the distribution and profile features of the soils are being investigated. It seems likely that the history of the development of the landscape will be most important, and it is already apparent that certain landscape features and associated soils, previously identified in other areas, may be recognized here too. As a result of these investigations it may then be possible to define rapidly over extensive areas the range of sites of varying ability to support perennial pastures.

(*b*) *Soil Chemistry*

The routine analysis of soil samples from the Liveringa survey and from the Mundaring pine plantation was carried out during the year, and reports compiled presenting the laboratory data on the soils of the Merredin, York-Quairading, and Meekatharra-Wiluna areas.

The application of a colorimetric method of analysis for phosphorus using ascorbic acid as a reducing agent for hydrochloric acid extracts of soils was critically examined with specific reference to soils high in iron.

The water-soluble polyphenolic components of jarrah (*Eucalyptus marginata*) and marri (*E. calophylla*) leaves and litter were separated, characterized, and identified with a view to subsequently studying their effect on soil materials. The major components were leucocyanidin and leucodelphinium, the glycosides of quercetin and myricetin, hydrolysable tannins composed of gallic acid–ellagic acid–sugar, and free gallic and ellagic acids. The concentrates containing these compounds, pure gallic and ellagic acids and a pure flavonal glycoside, were tested for their ability to dissolve iron oxide. Gallic acid and the hydrolysable tannins were found to be the active components in the jarrah, marri, and other eucalypt leaves.

In connexion with studies on the growth of *Pinus radiata* on lateritic soils, all available analytical data on soils of the pine plantations in the Darling Range have been extracted from the records of the Western Australian Forests Department and the Government Chemical Laboratory. Comparisons with actual growth of pines on these sites suggest that the trees may be able to tolerate lower phosphate levels in areas to the south with a higher rainfall and a longer growing season. An experimental program has now been initiated including tree injection treatments for curative purposes, pot and lysimeter experiments, a field trial involving the planting of pines following varying periods under leguminous pastures, and soil mixture studies.

3

Division of Plant Industry

1. General

The Organization's main concentration of research on plants is undertaken at the Division of Plant Industry which has its headquarters at Canberra. All returns from the land stem primarily from plants, either as pastures or crops, and the research of the Division relates to problems which are fundamental to agricultural production in Australia.

The work of the Division of Plant Industry is complementary to activities of the State Departments of Agriculture, which serve more immediate local needs of the farming industry. The Division has experimental farms and regional laboratories throughout the Commonwealth.

There are a number of other C.S.I.R.O. establishments investigating plant and pasture problems. The Division of Tropical Pastures studies the pastoral industry of northern Australia with the aim of supplementing and replacing native pastures with more productive sown pastures (*see* Chapter 4).

The Division of Land Research and Regional Survey is carrying out broad-scale ecological surveys to assess land use potential and investigate problems of agricultural and pastoral development. The work of these regional surveys is reported in Chapter 13, Section 2. This Division's investigations on crops, fertilizers, plant diseases, tillage, and native and introduced pastures under irrigated and dryland cultivation at the Katherine, Kimberley, and Coastal Plains Research Stations are reported in Chapter 13, Sections 8, 9, and 10.

Research by the Division of Biochemistry and General Nutrition on mineral nutrition of plants, and pasture plants in relation to animal nutrition is reported in Chapter 10. The work of the Fodder Conservation Section is reported in Chapter 15 and that of the newly formed Wheat Research Unit in Chapter 19.

Work on special local problems of irrigation districts is undertaken by the Irrigation Research Stations at Merbein, Vic., and Griffith, N.S.W. (*see* Chapter 5). The Division of Entomology is carrying out work on biological control of weeds, insect pests of pastures and crops, and insect vectors of virus diseases (*see* Chapter 11). The Division of Soils studies the complex chemical, physical, and biological processes in soil which influence fertility and growth of plants (*see* Chapter 2).

In Chapter 46, Section 4, is recorded the work of the Division of Meteorological Physics on meteorology for agriculture; in Chapter 9 research undertaken by the Division of Animal Physiology on pasture plants in relation to animal nutrition; and in Chapter 34 the work of the Organic Chemistry Section on alkaloids in Australian plants (*see* Section 5), stock poisons in plants injurious to animals (*see* Section 6), and the nature of chemical compounds exuded by the roots of growing plants (*see* Section 7).

The Engineering Section studies engineering problems relating to such matters as ploughing, mowing, silage loading, wheat storage, application of dissolved gypsum to pastures, and development and construction of the phytotron (*see* Chapter 16).

The major activities of the Division of Plant Industry have for many years been concerned with establishment, utilization, and maintenance of improved pastures throughout the diverse climatic regions of Australia. Research in agronomy, ecology, plant breeding, and plant nutrition has been pursued with the main aim of improving pastures. Work is also directed to other crops of economic importance such as tobacco and wheat. Complementary to these activities, strong research teams have been established in genetics, microbiology, biochemistry, and plant physiology to undertake fundamental research on plants.

Designs have reached an advanced stage for the building and controlled environment cabinets of the phytotron to be erected in Canberra (*see* Chapter 16, Section 2).

Work commenced on two new buildings for the Division in Canberra. One is a three-floor laboratory building to house Biochemistry, Biophysics, and Agricultural Physics. The other is an extension of the Biology Building to provide improved facilities for the geneticists.

A second "workshop on quantitative inheritance" was conducted during the year and was attended by geneticists from universities, State Departments of Agriculture, and C.S.I.R.O.

A discussion on "Ionic Behaviour in Polyelectrolyte Systems", organized by the Biochemistry Section, was attended by 80 scientists from all parts of Australia.

Cooperation has continued in training schemes for F.A.O. and Colombo Plan Fellows, and the Division has collaborated in research programs with the various universities, State Departments of Agriculture, and other Divisions.

2. Plant Introduction

(1) *International Exchange.*—In contrast to the previous year, the number of introductions received from overseas was relatively small. This reduction in numbers was largely due to the fact that no plant collectors were operating abroad during the year, while the resources of the Plant Introduction Section were fully taxed in handling the larger numbers of introductions made in previous years.

However, plans were developed for further collecting missions, which will result in a great increase in introduction activities in the near future.

Most of the introductions received consisted of varieties of crop and pasture plants obtained for specialists both in C.S.I.R.O. and in the State Departments of Agriculture. Requests for plant material from collaborators within Australia, and especially from overseas scientists, continue to increase, and have involved much work in critical quarantine checking and treatment of all samples despatched. In this work, close collaboration has been maintained with the Plant Quarantine Section of the Department of Health.

(2) *Preliminary Testing.*—About 2000 recent introductions have been under trial during the year in quarantine nurseries at Canberra, Perth, and Brisbane. Work at the latter centre has been reorganized to permit testing of a wider range of both pasture and grain legumes adapted to conditions in subtropical Australia. Facilities are still inadequate for the introduction and testing of tropical species, but it is hoped to establish an introduction station in the Northern Territory to meet the requirements of a more active program of tropical plant exploration.

At the Canberra station, about 350 new introductions, mainly of perennial grasses, were established during the year. Those showing promise include a strain of *Bromus inermis* from Turkey, and two introductions of tall fescue from Sweden. A strain of *Phalaris tuberosa* from South Africa, and one of *Secale montanum* from Hungary, showed continued good development in their second year of trial, and both will be tested in a range of environments in south-eastern Australia.

Most of the new introductions under trial in Western Australia are species collected on an exploration mission to Chile. At the present stage, interest is centred in grasses of the genera *Briza* and *Bromus*, and in the legumes *Hosackia subpinnata*, *Trifolium megalanthum*, and species of *Adesmia*. Full evaluation of these species will be a lengthy process, as many of them make slow growth in the initial stages and involve special nodulation problems.

(3) *Agronomic and Regional Trials.*—A feature of the year has been the increase in commercial utilization of pasture plants introduced and studied in earlier years. Buffel grass strains from Africa have been increasingly sown in many parts of Queensland, while there has been a very rapid development of *Sorghum almum* both in Queensland and in northern New South Wales. Also in New South Wales, a variety of *Bromus inermis* has been released commercially, while varieties of tall fescue, introduced some years ago, have been distributed for farm trial on the Northern Tablelands and elsewhere. New annual clovers from the Mediterranean region are under farm-scale trial in Western Australia, while improved varieties of vetch have been bulked up for large-scale distribution.

Advanced agronomic testing at Canberra has been concerned mainly with perennial grasses of the genera *Phalaris* and *Bromus*. Two introductions of Ronpha grass from South Africa have been outstanding for productivity among the *Phalaris* species and hybrids tested, and they have also given good performance at several regional centres. Special attention is also being given to the "El Gaucho" strain of *Phalaris tuberosa* from Argentina, which is reputed to hold its seed at maturity much better than other strains of this species, and hence to give higher seed yields. None of the more recent introductions of *Bromus inermis* has outyielded the Achenbach variety, now released commercially, but some of the Turkish introductions which are later-maturing and finer in leaf and stem may have value under different conditions.

Regional trials have been established at several centres in the Tumut-Tumbarumba region, both to assist in the evaluation of *Bromus inermis* and other grasses in an area of more favourable rainfall than that of Canberra, and also to form part of a chain of testing facilities in a transverse from the coast to Deniliquin in southern New South Wales. At coastal centres, particular attention has been given to *Lotus maroccanus* and other species of the genus. The Moroccan species appeared promising in the first year of trial, but suffered heavy mortality at the end of the season. Attempts are being made to obtain more perennial types.

In north-western New South Wales the main problem under investigation is the search for free-seeding, summer-growing, pasture legumes, capable of making full use of the predominantly summer rainfall and also of combining well with the grasses which have been shown to be adapted to the region. Several trials have been established, though they have been hampered by unfavourable seasonal conditions.

The program of experimental work in Western Australia involves yield trials of grain legumes and cereals and defoliation studies of pasture grasses and legumes, the main objectives being a progressive sorting out of available varieties, leading on to regional testing and eventual release of the more valuable introductions. Seed multiplication of about 22 grasses and legumes is in progress, as a preliminary to fairly large-scale field trials.

(4) *Plant Geography*.—Studies of distribution of the larger tribes of grasses throughout the world have been continued. A paper has been accepted for publication on the subfamily Fragrostoideae which is especially prominent in the flora of inland Australia. Its world distribution shows a striking correspondence with regions of hot, arid climate, with predominantly summer or non-seasonal rainfall.

Distribution maps have also been prepared for some of the smaller tribes, and a similar analysis is being undertaken with the Festuceae and related tribes, all of which occur mainly in the temperate regions of the world. The taxonomic relationships of these tribes are very confused, and geographical studies should help to clarify the position.

Sampling continued of mixed populations of *Phalaris tuberosa* grown at selected marginal centres in New South Wales, and all the sample populations have been transferred to the new Ginninderra Experiment Station to permit later comparative study. The dry seasons experienced at some of the marginal centres have led to considerable mortality of plants, and study of survivors may lead to development of strains better able to withstand climatic stresses.

(5) *Taxonomy and Systematic Botany*.—A major revision of the Australian species of *Nicotiana* has been completed during the year, involving description of

five new species and two new subspecies. This revision is based largely on collections made in many parts of Australia, and which have also provided material for genetic studies.

A study of the phytogeography of the Australian region has been completed and has been published as a special issue of the *Australian Journal of Botany*. Progress has also been made with the Dictionary of Australian Plant Genera, and this should be published in the near future.

Further taxonomic work included preparation of a paper describing new species of *Triodia*, mainly from central and Western Australia, and nomenclatural and taxonomic studies of the genus *Asterolasia*. Current work is concerned mainly with the preparation of a Handbook to the Flora of the Australian Capital Territory. Accounts of 22 families of plants occurring in the A.C.T. have been completed.

3. Genetics and Plant Breeding

(*a*) *Subterranean Clover*

(1) *Subspeciation*.—F_1's of crosses among strains from the western Mediterranean, and between these and Australian and eastern Mediterranean strains, disclosed a fairly extensive western Mediterranean "subspecies" distributed in Algeria, Morocco, Canary Is., and the Iberian Peninsula. No representatives of this have been found in Australian strains. An additional strain from Portugal was incompatible with all other groups identified to date.

(2) *Natural Selection*.—Mixed hybrids and parental pure lines were sown at 17 locations to follow the effects of natural selection.

Analysis of mixed pure-line populations has shown large changes in 4 years. The variety Tallarook, which originally comprised 30%, now contributes less than 2% in southern locations, 7% in the north. Mount Barker, originally 6%, has become dominant at most localities. Thus population composition can change very rapidly in response to particular seasons.

(3) *Seed Dormancy*.—Studies on mechanisms of seed dormancy have been continued. Low pH (2.5–3.0) has been found to cause radicle elongation, but not necessarily germination. The role of the testa is now under investigation.

(4) *Resistance to Subterranean Clover Stunt Virus* (*In collaboration with the Division of Entomology*).—Resistance to subterranean clover stunt virus has been located and its inheritance studied. Incorporation of resistance from Tallarook and other sources into a series of agronomically useful lines, covering a range of maturities, is proceeding. The new variety from Western Australia (Carnamah) is being used as a source of earliness. Many of the best producers in sward trials (see below) are resistant.

(5) *Development of Improved Agronomic Types*.—Tests at Kojonup, Deniliquin, and Canberra always placed the selection 1/34 in the top rank of lines tested. Its resistance to rust and virus make it the most promising candidate for replacement of Bacchus Marsh. It is being widely tested in New South Wales, Victoria, and South Australia.

Grazing trials of the best hybrid and back-cross selections showed that their ability to recover from heavy grazing compared more than favourably with Bacchus Marsh.

(*b*) *Lucerne*

(1) *Variety Trials*.—Variety trials were conducted at Denliquin, Canberra, Armidale, and Milton to evaluate varieties as breeding material.

At Deniliquin, Hairy Peruvian, African, and Indian outyielded Hunter River, both in winter and summer, under grazing or cutting, and when irrigated or on dry land.

At Canberra, Du Puits produced 30% more dry matter than Hunter River during the summer. During the winter Hairy Peruvian produced 140% more than Hunter River.

The superiority of Hairy Peruvian, African, and Indian, was also demonstrated at Milton.

(2) *Inheritance of Creeping Root*.—Analysis of data from Canadian material (in collaboration with Dr. Heinricks, Canada) has shown that genotypic variation in this material is predominantly additive, but this is not so for winter hardiness.

However, F_1's of winter-growing strains (Hunter River, Hairy Peruvian, African, and Indian) crossed with selections from the creeping rooted Canadian Rambler showed 3% creeping rootedness at Canberra. The F_2 and double cross progenies exhibited an average of 5%, with some outstanding families of 40% creepers. These results indicate the presence of non-additive gene effects.

Selection of lines combining creeping rootedness with winter growth is in progress in an effort to produce useful grazing types.

(3) *Heterosis*.—To obtain heterotic effects under sward conditions, half diallelled F_1 lines of nine parental plants (Hunter River, Hairy Peruvian, and Indian) were established in row sward conditions. Winter yield data demonstrated highly significant general combining ability effects, but specific combining ability effects were not significant. Summer yield analysis showed the importance of both additive and non-additive gene effects.

(4) *Spaced Plant Sward Relationships*.—The study of the relationship between spaced plants and sward conditions on selected high and low forage yielding clonal plants indicates that effective selection can be carried out on spaced plants for winter growth but not for summer production.

(*c*) *White Clover*

Adaptive Mechanisms in Trifolium repens.—The adaptive significance of the *Ac* and *Li* genes has been demonstrated and is being followed by a study of the physiological significance of *Ac*, *Li* gene products and the mechanism of adaptation.

(*d*) Phalaris

(1) *Top Crossing in* P. tuberosa.—Work is continuing on the selection and breeding of *Phalaris tuberosa* to combine the best features of the well-adapted

Australian commercial strain with those of selected ecotypes from the Mediterranean region.

Top crossing of a wide range of introductions to Commercial *Phalaris tuberosa* and a Turkish introduction has been completed. The F_1 families are currently being evaluated at Canberra and Wagga. Significant differences between crosses were found in the first year with respect to seedling vigour and flowering time. Yield data, with emphasis on winter growth, will be obtained from the trial during the current year.

(2) *Truncation Selection in* P. tuberosa.—A truncation selection program has also been initiated based on a population of F_2 recombinants derived from a polycross of 30 selected F_1 parents. The first selection for seedling vigour has been completed, and subsequent selections will be based on flowering time, and autumn and winter yield. In this connexion, efforts are being made to devise more rapid and reliable means of selecting for winter growth during the initial year of establishment.

(3) *Interspecific Hybridization.*—Crosses between *P. tuberosa* and *P. arundinacea* have been successful, and a total of 60 F_1 families are being tested in the field. The hybrid appears to have wide adaptability and will outyield *P. tuberosa* during both winter and summer. The production of a range of fertile allopolyploids using colchicine is now being attempted. The hybrid between *P. tuberosa* and the annual *P. minor* has shown promise as a short-term perennial, and a wide range of F_1's, allopolyploids, and back-cross derivatives are now undergoing field trials at Canberra and Wagga.

(4) *Polycross in* P. coerulescens.—Twenty-one top-cross F_1 families have been polycrossed and their progeny sown. Persistent and productive recombinants will be sought in the second year in an attempt to overcome the main weaknesses of this species.

(5) *Cytology.*—A survey of the *P. arundinacea* introductions has revealed the presence of two chromosome races, one with 28 and the other with 42 chromosomes. Both races have been used in crosses with *P. tuberosa*, and a study of the F_1's and allopolyploids has been undertaken to provide information for the hybridization program, and also to investigate the origin of the chromosomal polymorphism in *P. arundinacea*.

(6) *Estimation of Genetic Parameters.*—An experiment has been initiated to provide genetical information of direct application to the *Phalaris* improvement program. Attention has been confined in this first experiment to the assessment of the potential improvement likely from artificial selection within the Australian Commercial strain of *P. tuberosa*. Observations have been made from which it will be possible to infer the heritability of seedling vigour within the population, the magnitude of the genetic correlations between its various components, and the effect on seedling vigour of seed size. In the current season, observations will be made of flowering time and seed weight so that the heritabilities of these characters can be obtained, and genetic correlations between the three commercially important characters determined.

In addition to providing useful information for breeding practice, it is intended that the experiment should illustrate recent theoretical work on optimum design for estimation of genetic parameters, and so provide a guide for other workers faced with similar problems. The importance of some sources of experimental error is also to be estimated from the same material, to aid in the design of future investigations of this type.

(*e*) *Grass Strain Trials in Wagga District*

The autumn and winter productivity and persistence of strains of five potentially useful short-term perennial grasses have been measured through 2 years at Lockhart and Wagga. The results indicate that a breeding program may be warranted in *Ehrharta colycina*, in addition to those in progress in *Hordeum* and *Phalaris*. Strain trials of summer growing perennials were continued.

(*f*) Hordeum bulbosum

Attemps to produce awnless forms of *Hordeum bulbosum* are continuing. Several hundred awnless *H. vulgare* × *H. bulbosum* pollinations were made and three vigorous hybrids have been produced from the 55 embryos cultured. These will be back crossed to *H. bulbosum* and fertility restored by chromosome doubling. Screening for awnless mutants after X-ray and ultraviolet treatment has so far failed to reveal any dominant mutants. Progenies are being raised for screening for recessive mutants.

(*g*) *Tobacco*

(i) *Resistance to Blue Mould*

(1) *Introduction of Resistance from Other Species*.—The breeding for resistance to blue mould is continuing. Resistance has now been introduced into *Nicotiana tabacum* from three species, namely, *N. debneyi*, *N. goodspeedii*, and *N. knightiana*. The resistant plants, in general, have fewer leaves which are smaller, narrower, and coarser than those of the commercial varieties.

The resistance to blue mould, no matter what its source, has been inherited as a single dominant gene in the field at Mareeba — as a single dominant gene in the field, but with a deficiency of resistant plants (varying in amount from year to year) at Myrtleford, and in an irregular manner not suggesting any simple genetic ratio in greenhouse tests at Canberra.

One line, in which resistance has been introduced from *N. debneyi*, when grown at Myrtleford compared favourably with commercial varieties in the number and size of harvestable leaves. This line is being tested for commercial suitability.

(2) *Induction of Resistant Mutants in* N. tabacum.—Progenies from 1694 seeds treated with X-rays, gamma rays, neutrons, and chemical mutagens and from 1268 pollen grains treated with X-rays and ultraviolet radiations have failed to yield resistance combined with good agronomic characters. All of the supposed mutants reported last year are now thought to be contaminations from the disease transfer program.

One line isolated from the progeny of seed treated with triethylene imino-triazine has the highest level of resistance so far located from either the mutation or the resistance transfer program. This line has low seed germination and small coarse leaves.

(ii) *Tall Mutant*

This mutant of the variety Virginia Gold is characterized by failure to flower in the first season in the field, plants continuing to increase in height and develop leaves instead of an inflorescence. Flowering is dependent on short-day conditions, but it is not yet certain whether a cold stimulus is also needed. Seedling progeny are inheriting the non-flowering character. Crosses with two varieties flowered in the first season, indicating that the character is recessive, but it is not yet known how many genes are concerned in its inheritance. Crosses have been made to incorporate this character into blue mould resistant lines.

(iii) *Ecotypes of* Peronospora tabacina

The pathogenicity of isolates of *Peronospora tabacina* from north Queensland and Western Australia was compared with the Canberra "test strain", which was originally obtained from Victoria. Varieties and species of *Nicotiana* and segregating progenies from species hybrids were used as test material. Qualitative and quantitative differences between the three isolates were demonstrated, indicating the presence of different ecotypes of the disease organism. The Canberra "test strain" was the most pathogenic of the isolates tested.

(*h*) *Wheat*

"Basal sterility" in wheat has been studied for a number of years for three principal reasons. Firstly, a progressive series of genotypes differing from each other in the extent of flower abnormalities opens possibilities for a study of the hereditary component of morphogenesis. This presumably is the first time such an attempt has been made. Secondly, the work has uncovered the possibility that ancestral genomes, from which hexaploid wheat was built, possessed genetic systems for flower formation which have been replaced, and hence have become non-functional. This phase of the study, therefore, is designed to shed light on the evolution of gene function in a high polyploid. Thirdly, interactions between genetic and environmental determinants of flower development have been discovered which are being further studied.

This report deals only with progress in the first and second phases.

Basal sterility is a condition in wheat, so far only found in speltoid mutants, in which flower formation in one or more basal flowers of some or all spikelets is impaired. The degree of flower abnormality varies from loss or reduction of the anterior stamen to complete absence of any flower parts. There is a pattern which is *variable* within the *ear*, where the apex tends to be least affected, but is *rigid* within *spikelets*, where the next higher flower never is more affected than the lower one, so that only if the basal (the first) flower is affected will the second one be affected, and so on.

Work in the Division had previously shown that the normal flower development in *vulgare* is determined by a single gene closely associated with the gene Q which determines the *vulgare* characteristics. It is only in the absence of Q, i.e. in speltoids, that basal sterility is found.

Work has been in progress with crosses between four speltoids, grading in flower development from almost complete normality to almost complete absence of the first three flowers.

In these crosses has been revealed a genetic system for flower formation consisting of at least one major gene and probably a large number of polygenes. Just as the *vulgare* factor for flower formation conditions the fertility of the *first* and subsequent flowers, so does the dominant gene (called A) condition the normal flower formation in the *second* and subsequent flowers. The polygenes are responsible for the frequency and extent of normal and abnormal flower development, subject to the overall control by the A gene.

The polygenic series appears to be linked with the A locus, and the same series is responsible for variation in flower formation in the first and in subsequent flowers.

In crosses between the speltoid series and unrelated *vulgare* wheats, it has been shown that all *vulgare* wheats tested so far possess some alleles which impair normal flower formation in the speltoid state. This has been confirmed in X-ray induced speltoids.

In the diploid ancestral genomes of hexaploid wheat, flower formation may have been conditioned by these gene systems now revealed in speltoids, and under the cover of the later-acquired Q factor these systems may have become disused and are now in a state of gradual disintegration.

Studies are continuing with the crosses already mentioned. Recent work includes crosses between the Division's speltoid series and selected tetraploid and hexaploid wheats.

(*i*) *Radiation Genetics*

(1) *Root-knot Nematode Resistance in Tomatoes* (*In collaboration with the Commonwealth Research Station, Merbein*).—Screening for mutants resistant to strain B of *Meloidogyne javanica* has been commenced by using tomatoes homozygous resistant to strain A. Approximately 30,000 plants representing 1325 treated seeds and 205 treated pollen grains were screened for combined resistance. Some plants survived the first test, and these are being retested.

(2) *Potentially Useful Tomato Mutants* (*In collaboration with the Commonwealth Research Station, Merbein*).—An early maturing vigorous mutant from South Australian Dwarf has been selected and is being subjected to further testing.

(3) *Mutation Rate Studies*.—Multiple recessive tester stocks are being developed for mutation rate studies.

(4) *Flowering Time Mutants in Subterranean Clover*.—Early and later flowering mutants, selected from M_2 populations of Tallarook irradiated with X-rays and neutrons, had a range in mean flowering time in the M_3 generation of 36 days, compared with 10 days for the early and late selection from an unirradiated population. The flowering time mutants which were morphologically indistinguishable from Tallarook had a range of 17 days between the earliest and the latest M_3 family means.

In the unirradiated population more progress was made in selecting for earliness than for lateness (3.8 days earlier, cf. 0.9 days later). However, in the irradiated population the variation induced was more symmetrical (6.4 days earlier, cf. 6.1 days later). This symmetry was maintained in the "Tallarook-type" mutants (4.0 days earlier, cf. 5.8 days later).

Early and late flowering mutants have been reirradiated and a second cycle of selection will be made.

Early and late selections have been made from M_2 populations of the variety Clare. The efficiency of selection will be measured in the M_3 generation.

(5) *Host-*Rhizobium *Symbiosis.*—An attempt is being made to extend the host range and efficiency of nitrogen fixation by the *Rhizobium*-plant symbiosis. Variation in the nodulating and nitrogen fixing ability of the bacteria will be induced by mutation, and genetic recombination.

(*j*) *Quantitative Inheritance*

(1) *Quantitative Studies involving* Arabidopsis thaliana.—The technique of growing plants of the species *Arabidopsis thaliana* in exactly controlled environmental conditions is being used to study various problems of quantitative inheritance. One program involves the genetic study of homeostasis. In this study an attempt is made to define measurable homeostatic parameters, to estimate these parameters for a group of 40 homozygous races, and finally, to study the inheritance of these parameters by use of a diallel crossing system.

In another project the genetic structure of overdominance is studied. A gene system involving a single major locus and an associated modifier system has been discovered which exhibits overdominance for late flowering. By a system of gene transfers it is hoped to break down the inheritance pattern into main effects of the major locus and the modifier system, and interactions between the major and modifier genes.

(2) *Quantitative Inheritance and Theoretical Plant Breeding.*—An attempt is being made to generalize the theory of selection to include epistasis and linkage. Two papers have dealt with mass selection. Work is now in progress on generalizing full-sib and half-sib selection.

(3) *Genetic and Developmental Homeostasis.*—With the use of *Drosophila melanogaster*, an attempt has been made to contrast the genetic homeostatic adjustment of an additive genetic quantitative character with that of a highly canalized character. The population has been disturbed from its equilibrium condition by means of artificial selection for each character separately, the change in reproductive fitness due to this disturbance measured, and the return of the population mean towards the unselected level on relaxation of selection determined. From an experiment of this nature valid inferences can be drawn as to the homeostatic strength of each character. The work has not yet been completed, but a sharp contrast can be drawn between the two characters, representing as they do markedly different genetic systems.

A theoretical discussion has been published of a model under which natural selection discriminates against extreme metric deviation in a quantitative character, genetic variation being maintained solely by mutation pressures. Predictions of behaviour under artificial selection have been shown to be identical with those to be expected from Lerner's homeostatic model of natural selection against high levels of homozygosity *per se*.

Consideration of the relationship between the genetical properties of a quantitative character, and the action of natural selection on the genetic system involved, resulted in a proposed classification of quantitative characters which seems likely to bear some relation to the way in which natural selection has shaped their genetical properties. This classification is the first which covers the complete spectrum of genetic variation from canalized genetic systems on the one hand, to highly non-additive genetic systems produced by uni-directional selection on the other. It is also probable that the degree of developmental homeostasis shown by a character is intimately bound up with its position in the classification proposed.

(4) *Experimental Check on Quantitative Inheritance Theory*.—Artificial selection involving a canalized character in *Drosophila melanogaster* has revealed that at different points on the scale of measurement, genetical properties of the character in the population are markedly different. An attempt is being made to obtain stable populations with means at different points along the scale. These populations should provide material for experimental verification of the predictions possible from quantitative inheritance theory over a range of genetic situations.

(*k*) *Recombination Frequency in the Tomato*

The objective is to study changes in recombination frequency at various stages of the plant's history, and to discover a method of altering the environment of the plant which will induce an increase in recombination frequency. Some 30 biologically active chemical sprays were tried without success. Likewise, neither changes in nutrient supply nor grafting were successful in increasing the recombination frequency. However, by a system of gene transfers, it was demonstrated that recombination frequency can be modified by genetic means. Therefore, the theoretical possibility exists of altering recombination frequency by artificial selection.

(*l*) *Biochemical Genetics*

(1) *A Thiamin-Requiring Tomato Mutant*.—As a contribution to the biochemical genetics of flowering plants, the chemical deficiency in a spontaneous lethal tomato mutant has been studied. Plants homozygous recessive for the mutation are almost completely devoid of chlorophyll, have small twisted leaves, and die a few weeks after germination. Treatment with organic supplements demonstrated that normal growth of the mutants followed application of thiamin (vitamin B_1). The specific chemical reaction lost as a consequence of mutation is either methylation of position 2 or activation of position 5 of the pyrimidine ring in the thiamin molecule.

(2) *Biotin and Thiamin Requiring Mutants of Arabidopsis*.—Physiological and chemical study of these mutants has been completed and the results prepared for publication. These mutants form examples of how genes, by controlling cellular chemical reactions, produce characteristic phenotypes. The biotin require-

ment is manifest only at relatively high temperatures (above 28°C) when plant growth is reversibly arrested. Model experiments indicate that the adaptive significance of this gene in wild populations may lie in its providing a mechanism for cessation of growth during periods of extreme heat.

(3) *Nature of Events Leading to Initiation of Vaccinia Virus Synthesis in Human Tissue Culture.*—On infection of a tissue culture monolayer with a suspension of vaccinia virus particles, a sequence of events commences leading to the ultimate multiplication of vaccinia virus within the infected cells. These events involve adsorption, penetration, and release of the viral deoxyribonucleic acid (DNA) into the cytoplasm and the eventual initiation of synthesis of viral DNA and viral protein.

Previous studies on the kinetics of initiation of virus multiplication demonstrate the existence of at least two time-consuming processes. One of these is of constant duration of some 3 hr, irrespective of multiplicity of infection. The other is of variable duration, which is multiplicity dependent, wherein the time course of onset of virus multiplication expressed as the rise in frequency of virus producing cells (P_T) with time (T) is:

$$P_T = 1 - \exp[-m\{1 - \exp(-k\overline{T - t})\}],$$

where m is the average multiplicity of infection, and t the duration of the above constant period.

Attempts are now being made to determine the order of these two time-consuming processes, and the nature of the biochemical events consummated during these preparatory periods by treating the system with protein and nucleic acid inhibitors.

Nucleic acid metabolism does not seem to be implicated in either of these processes, and no conclusion can be drawn yet about the role of protein synthesis.

Emerging from these antimetabolite studies is the fact that, once initiated, synthesis of virus protein (as revealed by specific conjugated fluorescent antibody staining) and synthesis of vaccinia DNA (by autoradiographic studies of tritiated thymidine incorporation) are totally independent processes.

(4) *Cytoplasmic Replication of Vaccinia DNA in Human Cancer Cells Blocked with respect to their Nuclear DNA Replication.*—Incorporation of 5-bromodeoxyuridene (5-BUD) into human cancer cells (Line KB), in the presence of antimetabolites of thymidylic acid biosynthesis from deoxyuridylic acid, proceeds until 50% of the thymine residues in the DNA is replaced by 5-bromouracil. Such DNA is incapable of further replication, even when returned to optimal nutrient conditions. By means of preincubating tissue culture monolayers of KB cells for 72 hr in the presence of 5-BUD, some 98% of the cells lose their ability to undergo further DNA replication and consequently further cell division. Such cells when infected with vaccinia virus in normal medium are capable of supporting cytoplasmic replication of the vaccinia DNA, without revitalizing the nuclear DNA replicating ability.

This result indicates that 5-BUD incorporated into this particular line of cells in some way jams the template mechanism in DNA replication. This property of 5-BUD is far from universal in that the DNA of normal marrow cells, mouse liver cells, phage, and bacteria is not affected with respect to its ability to replicate.

Further studies are in progress with the reagent, 5-BUD, to see if it interferes with replication of vaccinia DNA. So far it is known that 5-BUD does not inhibit the synthesis of vaccinia protein.

4. Microbiology

(*a*) *Rhizobial Studies*

(i) *The Site and Mechanism of Nitrogen Fixation in Legume Nodules*

Experiments on the distribution of isotopic nitrogen (^{15}N) in centrifugal fractions of soybean nodules which had been exposed to labelled atmospheres, showed that the ^{15}N appeared first in the host membranes which enclose the bacteroids. The bacteroids were not labelled at all. The initial steps of nitrogen fixation appear to occur in these membranes, from which the nitrogen passes into the soluble fraction.

The following hypothesis has been developed:

The nitrogen-fixing unit is thought to be the membrane envelope (10^{10} in each nodule) with its contents of several bacteroids bathed in haemoglobin in solution. Photosynthetic products from the host pass into the units and are partially oxidized by the bacteroids. Reducing power is thus generated which is coupled to the nitrogen-activating sites in the membranes by an electron transport chain involving haemoglobin. The activated nitrogen is, as a result of this reducing effect, ultimately converted to ammonia, which is in turn combined with the products of the incomplete substrate oxidation in the bacteroids to form the amino acids which become available for host plant nutrition.

Molybdenum has been shown to be a specific requirement for nitrogen fixation by legume root nodules. In view of the structural and ^{15}N studies it seemed desirable to know the distribution of this element among the nodule fractions. The dry weight distribution shows that in the intact nodule the soluble fraction contains 58% of the molybdenum, and the bacteroids 15%, and that the balance is divided between the membranes and the residue.

(ii) *The Effect of Environment on Nodulation and Nitrogen Fixation*

A controlled-environment cabinet has been constructed that provides a variety of separate top and root temperatures for the plants and a reasonably high light intensity. The principal results obtained so far from its use are:

There is a marked reduction in the amount of nitrogen fixed by Mount Barker variety of subterranean clover as the root temperature decreases. Nodulated plants fixed 0.16 mg nitrogen per plant after 20 days at a root temperature of 4.5°C and 2.60 mg nitrogen per plant at 18°C. Figures for the nitrate controls were 0.35 and 2.90 mg respectively. However, the Dwalganup variety fixed as much nitrogen as the nitrate controls, when grown at 4.5°C. With Mount Barker variety there were bacterial strain effects, which were virtually absent with Dwalganup.

The effect of high temperatures on nodulation of *Medicago tribuloides* was studied and some strains of *Rhizobium melilotii* were more sensitive to high temperatures (28–32°C) than others, the degree of the effect depending upon the particular host plant with which they were in association.

(iii) *Nodulation Studies*

In experiments with subterranean clover, incorporation of inoculation within the pellet, by mixing with the adhesive, was more successful than external application of inoculant to the pellet. Lime-pelleted seed nodulated as well as that pelleted with blood-bentonite, but when the inoculant population was low, the latter proved best and was also superior to milk powder, or yeast extract. Magnesium salts and maltose had no effect when incorporated into the pellet. Preinoculated pellets of blood-bentonite or lime, stored for 28 days before sowing, gave satisfactory nodulation.

Populations of *Rhizobia* capable of nodulating subterranean clover may possibly be built up in the soil in the rhizospheres of other legumes.

Trifolium glomeratum, *T. hirtum*, and *T. incarnatum* were sown together with *T. subterraneum*. Only *T. glomeratum* conferred considerable benefit on the nodulation of subterranean clover.

(iv) *Ecological Studies*

(1) *Subterranean Clover Establishment.*—In the tablelands division of New South Wales, where the winters are cold and the soils may contain populations of *Rh. trifolii* of a low order of effectivity, difficulties are encountered in the establishment of subterranean clover. Varieties of subterranean clover and the strains of *Rh. trifolii* at present available commercially may not prove satisfactory under conditions of high elevation and low winter temperatures.

In podzolic soils, modification of the topsoil environment by naturalized clover species and cultivation practices have been shown to be important in the success or failure of nodulation of subterranean clover. In particular, sheltering clover seedlings (by tussocking or deep furrow ploughing at right angles to the prevailing wind direction) assists winter nitrogen fixation.

Subterranean clover collected from naturalized material grown at high elevations, and introduced material from similar situations, are being compared with present varieties with regard to winter growth and nitrogen fixation. Some of these varieties do not appear to combine well with the present commercially available clover nodule bacteria, although several introduced subterranean clover varieties which nodulate well at low temperatures are being studied.

(2) *Ecology of Field Populations of* Rhizobium meliloti.—Distribution is being studied of medic nodule bacteria in grey and brown soils of the Upper Darling area and in brown acid soils of central New South Wales.

Thirty-three species of *Rh. meliloti* were isolated from brown acid soils of the Macquarie region of New South Wales. Their behaviour regarding nodulation and N_2 fixation was studied with seven spp. of *Medicago* and two spp. of *Melilotus*.

For nodulation, the hosts fell into three groups and the bacteria into two, as follows:

	Bacteria A	*Bacteria* B
(*a*) *M. denticulata, M. sativa, M. tribuloides, M. minima, Mel. alba, Mel. indica*	+	+
(*b*) *M. praecox, M. orbicularis*	+	−
(*c*) *M. laciniata*	−	+

For nitrogen fixation, the hosts could be arranged in five groups each of which behaved in a distinct, but complex way with the bacterial strains isolated.

(v) *Host and Bacterial Strain Specificity in Symbiotic Effectiveness*

Successful introduction of new species or varieties of legumes into agriculture depends to a large extent on the availability of *Rhizobium* strains capable of producing nitrogen-fixing nodules on the host. Comparative field tests of a new legume are of little value, unless a fertilizer nitrogen control is used, if effective nodules are absent, or if the full peak of effectiveness is not reached by the nodules produced.

The Microbiology Section maintains an extensive stock culture collection of *Rhizobium* strains, and where there are gaps in coverage of potentially important introductions, new strains are being sought.

The following are two examples of work which emphasize the importance of this work to plant introduction and legume breeding projects.

There was considerable variation in the ability of 15 strains of lucerne to symbiose effectively with six strains of *Rh. meliloti*, with considerable evidence for host-strain specificity. Some varieties also gave very variable fixation when nodulated with any one strain of bacteria.

Five species of *Lotus* were tested for symbiotic effectiveness with a number of strains of *Rhizobium*. Strains producing effective nodules on *L. corniculatus* are also effective with *L. arvensis* and *L. tenuis*, but ineffective with *L. uliginosus* and *L. angustissimus*. The reverse is also true, strains effective with *L. uliginosus* and *L. angustissimus* being ineffective with the other three species.

(*b*) *Virus Studies*

(i) *Mechanisms of Virus Infection*

(1) *Inactivation of Tobacco Mosaic on Leaves of* Nicotiana glutinosa.—The fate of virus particules which failed to infect and multiply was examined in leaves of *N. glutinosa* inoculated with tobacco mosaic virus. Plants were maintained at 25°C and biological assays were made at 21 intervals of time during a period of 30 hr following inoculation. In the latent period, which precedes the phase of detectable virus multiplication, inactivation of virus in general followed a straight line course. From studies of virus inactivation *in vitro*, it was postulated that

irregularities in the pattern of virus inactivation in the leaf may be due to adsorption and release from cellular particles in wounded cells.

Infectivity of leaf samples was enhanced by impregnation of leaves with buffer prior to homogenization and assay. It could not be shown that this was due to preservation of infective ribonucleic acid in assay samples.

(2) *The Sites of Virus Infection of* N. glutinosa *Leaves.*—Distribution of local lesions on the surface of *N. glutinosa* leaves has been shown to deviate from the expectation of a Poisson distribution. As the leaf grows, the region of the leaf producing the greatest number of lesions per unit area changes from the tip to the base. This is coincident with the basipetal succession of epidermal cell division, and it is suggested that cell division may play a direct part in cell susceptibility to virus infection.

(3) *The Effects of Wound Healing on the Infection Process.*—The U_2 strain of tobacco mosaic virus, when inoculated to *N. glutinosa* leaves in Sorensen's buffer, undergoes a change in sensitivity to inactivation by ultraviolet light, during the first 6–9 min. The ultraviolet sensitivity then remains constant for a period of 2 hr. However, when inoculated in distilled water only, the sensitive period is extended to about 18 min. Wound healing of plant cells may play a part in infection and healing may be hastened in the presence of buffer.

(ii) *Infection of Peanuts with Tomato Spotted Wilt Virus*

Spotted wilt virus has been identified as causing a disease of peanuts in Queensland. A survey was made of the incidence of the disease at Kingaroy, maximum disease incidence in an individual crop being 5–6%. Reduction of seed yield was shown in diseased plants, and although seed developed lesions the disease was not seed-transmitted in mature seed. Infective virus was found in seed coats of immature seed. Several new hosts of the disease have been identified.

(iii) *Virus Diseases of Cereals, with Particular Reference to Barley Yellow Dwarf Virus*

Presence of this virus has been shown in wheat and oat crops in Queensland, New South Wales, and the Australian Capital Territory. *Rhopalosiphum pódi, R. maidis,* and *Macrosiphum avenae* subsp. *miscanthi* were shown to be vectors of the disease. *Hordeum leporinum* and *Bromus unicloides* acted as alternate hosts. Some strains of the virus have been shown to be transmitted by all three vectors, but others are transmitted by specific vectors only.

(*c*) *Fungal Studies*

(i) *Mechanisms of Disease Resistance and Susceptibility*

(1) *Physico-chemical Basis of Resistance to* Peronospora tabacina *in Tobacco.*—Almost complete resistance to blue mould disease can be obtained in tobacco leaves by injecting spore suspensions of *Peronospora tabacina* into the stem of the plants. Histological examination revealed that the pathogen in the stem is established in the periphery of the secondary xylem, cambium, and external phloem. Penetration of the fungus through the leaf epidermis is subsequently reduced and its spread and development are inhibited. Time interval between stem

injection and leaf inoculation is important in terms of final host reaction. At low nitrogen levels, stem injection promotes early maturity of the plant and modifies leaf size. The protective effect of stem injection is persistent and is not affected by environmental conditions or soil nitrogen level.

Analysis of leaf samples for soluble amino acids and sugars showed distinct differences between susceptible and stem-infected plants. Under conditions of nutrient excess, stem-injected plants show an increased level of γ-aminobutyric acid and a lowering of aspartic acid, glutamic acid, and asparagine. Under conditions of low nutrient supply, levels of aspartic acid, glutamic acid, asparagine, glutamine, γ-aminobutyric acid, alanine, and lysine increase in stem-infected plants. In both instances, levels of other free amino acids are not affected, while the concentration of free sucrose, fructose, and glucose are raised in the stem-infected plants. While total level of phenols is not affected by stem injection, chromatography indicates the presence of a phenolic compound not detectable so far in healthy plants.

(2) *Disease Reactions of Plants, with Special Reference to the Phytoalexin Theory.*—An antifungal compound is formed in the endocarp of pea pods (*Pisum sativum*) following inoculation with *Sclerotinia fructicola*. Sensitive and precise biological and physical assays have demonstrated inhibition of germination of *S. fructicola* at a concentration of 10^{-4}M. The compound has been crystallized and named "Pisatin" (*see* Section 8(xi) of this chapter). Production of pisatin has been demonstrated *in situ* in pods and leaves, as well as in detached pods. The same compound is produced in response to a range of pea pathogens and non-pathogens and in all varieties tested. Pisatin concentration however, varies with the fungus used. Differential sensitivity towards pisatin has also been shown between fungi pathogenic and non-pathogenic to pea pods.

Several grams of pure pisatin have been prepared by processing several hundred pounds of field-grown peas.

Certain chemical and physical properties of pisatin have been described. Microanalyses are consistent with the molecular formula $C_{17}H_{14}O_6$, and it is optically active, the specific rotation being:

$$[\alpha]^{20}_{578\mathrm{m}\mu} + 265^\circ \ (c,\ 0.11 \text{ in ethanol}).$$

Pisatin is sparingly soluble in water, but soluble in a wide range of organic solvents. Ultraviolet absorption maxima are at 286 and 370 mμ in water.

Pisatin is stable in neutral or alkaline solutions, but is readily dehydrated by acid, probably with the formation of a double bond. This change is accompanied by a marked bathochromic shift in the ultraviolet spectrum. The product has been recrystallized and analysed, and appears to be an anhydropisatin $C_{17}H_{12}O_5$, which is optically inactive. The loss of the hydroxyl group is confirmed by the infrared spectrum.

Preliminary work on infection of *Phaseolus vulgaris* and *Capsicum fructescens* indicates that here again antifungal substances of the phytoalexin class are produced, but that these substances are chemically different from pisatin.

(3) *Resistance to* P. tabacina *in Strains and Species of* Nicotiana.—One hundred and twenty-six strains of 19 species of *Nicotiana* of Australian origin have been tested for resistance against blue mould. Species found to be highly resistant are *N. debneyi, N. exigua, N. megalosiphon, N. velutina, N. goodspeedii, N. occidentalis, N. rosulata, N. cavicola,* and *N. simulans.* Moderately resistant species are *N. sauveolens, N. excelsia, N. rotundifolia,* and *N. umbratica.* Of 32 strains of 24 American species tested, three showed slight resistance and all others were very susceptible.

It was found that isolates of *P. tabacina* from Canberra and Victoria gave similar reactions, while the disease developed more slowly in plants inoculated with isolates from north Queensland and Western Australia. Differences were not of a sufficiently high order to warrant designation of the separate isolates as strains.

(ii) *Environment and Disease*

(1) *Epidemiology of Blue Mould.*—A method has been developed for rating disease on individual tobacco plants grown under a wide range of field conditions and a satisfactory sampling method evolved. In 1959–60, the pattern of disease development in the Ovens Valley area was such that in crops planted with diseased seedlings, the whole crop soon became infected and provided spores for mass infection throughout the district. In other crops, single plants infected late in the season gave rise to only a limited number of further infected plants. Disease severity was shown to be related to age of plants at time of infection, to the number of plants infected, to the type of plant growth, and to the district in which the crop was grown.

Factors affecting the dissemination of conidia of *P. tabacina* have been studied. Spore release was inhibited by high humidity and continuous light or dark. The daily cycle of spore release was not dependent on changes in atmospheric humidity and was seldom associated with conditions favourable for widespread dissemination and survival of conidia. The daily cycle provides for dissemination of lower leaves of the sporulating plant and to adjacent plants. Dissemination at other times of the day and occasionally at the time of the daily peak provides for widespread distribution of conidia.

Sclerotinia fru

(2) *Epidemiology of Brown Rot of Stone Fruits.*—It has been confirmed that sporulation from fruit mummies and infected peduncles constitutes the primary spring inoculum of the disease. Mature fruit wholly covered by infection bear 10^6–10^9 viable condia, but their viability drops rapidly over a period of 2–4 weeks. Fresh sporulation can occur on mummies during the winter and spring periods, and it is estimated that during the spring period the average fruit mummy has a potential for producing some 10^6 viable, easily detachable spores. During the same period some 4×10^4 viable spores are produced per tree from peduncle sources. This study underlines the necessity for efficient fruit mummy removal from the orchard and the necessity for developing methods of control of peduncle infection.

A number of compounds have been screened, in greenhouse tests using rooted peach cuttings, for activity against brown rot infection. Griseofulvin, when applied systemically, gave 70–80% control of the disease.

Isolates of *Monilinia fructicola* from the Canberra and Griffith, N.S.W., areas show distinct differences in morphological and pathogenic behaviour. Hyphal fusions have been observed to occur freely between all isolates and evidence has been obtained that heterokaryosis occurs between strains.

Conidia show no significant loss of viability when stored over a range of temperatures between 0 and 30°C, and relative humidities over the range 0–100% for a period of 8 weeks. Examination of their sensitivity to ultraviolet light showed a killing-dosage relationship of 432,000 $\mu W/cm^2$ for relative humidities in the range 40–100%, but the lethal dosage increases considerably at lower humidities. Absorption of ultraviolet radiation appears to be the main cause of loss of viability of conidia under field conditions.

5. General Chemistry and Soil Fertility

(1) *Soil Fertility*.—Studies of soil changes taking place under subterranean clover pastures has been made at Crookwell, N.S.W. Previous investigations had shown increases in available nitrogen, sulphur, phosphorus, and exchangeable cations, and had indicated the importance of phosphate and sulphur from superphosphate top-dressings in the general build-up of fertility.

Laboratory, glass-house, and field experiments have been completed in an examination of the importance of the build-up of exchangeable potassium on the fertility of these soils. These results showed that potassium accumulated under these pastures plays an important part in preventing the occurrence of potassium deficiency in older pastures. The results also showed that removal of heavy hay cuts from these pastures could seriously deplete the available potassium reserve.

Close relationships were found between the exchangeable potassium of the soil and both the potassium content of the plant material and the uptake of potassium by the plants both in field and pot culture experiments. The measured decreases in exchangeable potassium of the soil during plant growth were insufficient to account for the total uptake of potassium by the plants, indicating that other sources of soil potassium were also available. It seems probable that the pasture plants themselves contribute appreciably to the conversion of non-exchangeable soil potassium to exchangeable forms.

(2) *Sulphur Availability*.—Recent work by the Division has shown that in most well-drained acid soils most of the soil sulphur is present in organic forms–only small amounts are present as free inorganic sulphur. A close relationship has been found to exist between the organic sulphur and total nitrogen for a wide range of soils. Alkaline soils, however, have often been found to contain a higher proportion of sulphur relative to nitrogen than acid soils. Alkaline soils are being examined to determine whether this difference is due to a higher proportion of sulphur in the soil organic matter under alkaline conditions or due to the presence of water-insoluble forms of sulphate.

Sulphate adsorption studies have shown that adsorption of sulphate by most surface soils is slight. However, appreciable amounts can be adsorbed by soil clays and significant amounts of sulphate may be adsorbed by some subsoil horizons. Little adsorption of sulphate has been observed at pH values greater than 6.0 and between pH 5.0 and 6.0 the amounts adsorbed are generally small. Most adsorption appears to take place at pH values below 5.0.

A water-insoluble form of sulphate has been found in one group of soils which appears to be associated with calcium carbonate. A range of soils and calcite samples are being examined for further evidence of this form of soil sulphur.

(3) *Soil Organic Phosphorus.*—Studies continued on extraction of organic phosphorus from a variety of Australian soils. Examination of the procedure developed by W. G. C. Forsyth in 1947 for the fractionation of fulvic acid on charcoal columns showed that the organic phosphorus present was adsorbed strongly onto the charcoal and could not be eluted completely even when extended washing with sodium hydroxide was resorted to. Extraction of organic phosphorus from soil by hot ammonia, sodium oxalate, and the oxine reagent of G. W. Boswall and W. A. Delong (1959) was shown to be less complete than extraction using sodium hydroxide. The products in each case were found to give unsatisfactory results when examined chromatographically and electrophoretically, the bulk of the organic phosphorus present being unresolvable into recognizable components.

In view of the unsatisfactory result obtained in these studies attention is now being given to the detection and estimation of possible breakdown products of organic phosphates in hydrolysates of soil. Progress has been achieved in estimation of inositol in hydrolysates from an alpine humus. The amount of inositol as phytate is equivalent to about 10% of the organic phosphorus in this soil.

(4) *Spectrochemical Investigations.*—Investigation of atomic absorption spectroscopic techniques for soil and plant analysis has been continued. This method is particularly suitable for the analysis of a number of elements of agricultural interest and highly satisfactory methods for the determination of sodium, potassium, calcium, magnesium, and zinc in plant material have now been developed. This technique has also now been applied to the analysis of exchangeable cations in soils.

Examination is now being made of the possible use of this method for the analysis of trace metals manganese, iron, copper, and strontium in plants. Preliminary work has shown that the method is likely to be sufficiently sensitive for the analysis of each of these elements but poor sensitivity is likely to prevent its use for the analysis of barium in either soils or plants. Appreciable chemical interference from extraneous ions in soil and plant digests have been observed with these elements and methods for overcoming this are being tested.

(5) *Nitrogen Availability.*—A study has been made of seasonal changes in mineral nitrogen in a 14-year-old *Phalaris*–subterranean clover pasture at Canberra by continued sampling. There is an accumulation of soil nitrate and some ammonia (up to 30 p.p.m. of nitrate nitrogen in the surface 0–4 in. layer) during the hot summer period when the *Phalaris* is growing only slowly and dry conditions are usual. This result contrasts with the more general overseas condition of low nitrate values and higher ammonia concentration under perennial pastures. Under the *Phalaris* pasture the level of nitrate nitrogen fluctuated throughout the autumn,

but generally remained moderately high. It decreased gradually during the winter to a very low level in August and September. Available nitrogen then increased to high levels again during late spring (November–December) during senescence of the clover.

Studies are also being made of the significance of available nitrogen during the invasion of pastures by thistles and of the effects of nitrogen fertilization and high soil-nitrogen status on the quality of herbage produced.

6. Plant Nutrition

(1) *Residual Value of Phosphorus Fertilizer.*—In experiments on the Southern Tablelands of New South Wales a major factor governing availability of residual phosphorus to plants appears to be the conversion of inorganic phosphorus to less available organic forms, through uptake by the plants themselves. This effect of conversion of phosphorus to less available organic forms can be more important than "fixation" of inorganic phosphorus. For the soils concerned, the main fall in residual value of phosphorus fertilizer occurs only after yield responses to phosphorus have been obtained. Fall in residual value is considerably less where a deficiency limits plant growth and inhibits uptake of phosphorus.

(2) *Rock Phosphate.*—Ground rock phosphate and superphosphate were compared as pasture top-dressings on two acid soils on the Southern Tablelands of New South Wales. Calcium sulphate was applied to prevent the occurrence of sulphur deficiency where rock phosphate was used. When the rock phosphate and superphosphate were applied to the pasture in one initial dose only, at the beginning of the trial, superphosphate gave higher yields in the first few years of the trial for equivalent levels of phosphorus applied. The rock phosphate and superphosphate both had a good residual value, and the yields obtained with the two fertilizers were not significantly different after the first few years. The total yield of pasture over the seven-year period was similar for both fertilizers where they were applied in one initial dose only.

(3) *Leaching of Phosphorus.*—Experiments using radioactive phosphorus on an acid sandy soil at Flinders Island showed that the phosphorus in superphosphate leaches rapidly from that soil. In these trials it was also found that dressings of lime retain considerable amounts of applied phosphorus in the surface soil. The results suggest that immobilization of phosphorus may be an important effect of lime on other acid sandy soils where unexplained pasture responses to heavy dressings of lime have been recorded.

(4) *Calcium Deficiency.*—Experiments were conducted on soils of the Southern Tablelands of New South Wales to determine whether there is a need for lime to correct calcium deficiency. Normal superphosphate dressings in use appear sufficient to provide the calcium requirements of subterranean clover.

(5) *Nitrogen Fixation.*—Following earlier work with lime-coated seed, a study is being made of other seed treatments that might also aid clover nodulation on problem soils. In addition, study of factors affecting symbiotic nitrogen fixation

is being continued, with particular emphasis on effects of phosphorus, calcium, and temperature.

(6) *Comparison of Species*.—It is apparent that lucerne fails on many soils where subterranean clover can be grown. A special study is being made of the nutritional requirements of lucerne on different soils in New South Wales.

(7) *Role of Elements in Plants*.—The Hill reaction activity of chloroplasts isolated from the leaves of mineral deficient tomato plants was measured and expressed on a per unit chlorophyll basis. Deficiencies of all the macronutrient elements resulted in chloroplasts with reduced Hill activity. Among the micronutrients, deficiencies of manganese, copper, zinc, boron, or molybdenum caused impairment of Hill activity in decreasing order of severity. Iron deficiency had no effect. The activity of chloroplasts from deficient plants was in no instance increased by adding the missing nutrient to the chloroplast suspension *in vitro*.

Absorption spectra of suspensions of chloroplasts from healthy and deficient plants and of 80% acetone extracts of these suspensions were compared. No shifts in the absorption peaks and no gross changes in the relative proportions of major components was found. In some deficiencies, however, a small but significant decrease was observed in the ratio of chlorophyll *a* to chlorophyll *b*.

Chloroplasts from healthy and deficient plants were assayed over a range of limiting light intensities up to saturation, and the effect of light intensity on the degree of impairment was recorded. Degree of impairment due to deficiency was also measured at two different temperatures (10 and 30°C) with saturating light. From these results it is tentatively concluded that zinc, copper, boron, and probably potassium and phosphorus deficiencies interfere with reactions in the reducing sequence whereby electrons are transferred to the added oxidant. Deficiencies of manganese, molybdenum, nitrogen, sulphur, calcium, or magnesium cause impairment of reactions in the hydroxyl sequence terminating in liberation of molecular oxygen.

7. Plant Physiology

(1) *Hormonal Control of Plant Growth*.—In support of the hypothesis that dividing plant cells produce a cell division stimulator, such a substance was detected in a number of meristematic tissues and was not detected in these tissues when cell division had ceased. The tissues investigated were apple, pear, quince, plum, and tomato fruits, hardwood and softwood cambium, and flax root pericycle.

Tobacco stem conducting tissue, which can induce division in adjacent pith tissue, also contained a cell division stimulator.

To isolate and chemically identify a natural cell division stimulator, 1800 lb of apple fruitlets were harvested 2 weeks after pollination, when cell division activity was maximal. The fruit have been extracted and the chemical properties of the stimulator are being investigated to develop an isolation procedure.

From the chemical properties of the stimulator so far investigated, the following tentative conclusions about its nature may be drawn: (i) it is not a protein, (ii) it is not a macromolecule, (iii) it contains no strongly basic or acidic groups, (iv) it is not a β-glucoside.

The chemical properties of the stimulator from apple are remarkably similar to those of a stimulator detected in coconut milk. Hence cell division stimulators from diverse sources may have similar structure.

(2) *Protein Synthesis in the Developing Wheat Grain.*—This project is an attempt to correlate the ontogenetic pattern of some enzymes with the synthesis of specific protein fractions in the developing wheat grain.

Earlier observations on the variety Insignia have been confirmed and extended on the variety Festival (favourable because of its rust resistance). Noteworthy is that again a peak in the activity of glutamyl transferase was found at 12 days after anthesis, i.e. at a time when gliadin is hardly detectable in the grain.

Glutamyl transferase is located almost entirely in the grain coat. The peak of activity of glutamyl transferase is a reflection of the developmental pattern of specific layers in the grain coat.

In the harvest series estimates were also made of the content of leucine-activating enzyme. Activity rose concomitantly with that of glutamyl transferase, but it showed a much broader peak; in the latest harvests the activity was nil. At 16 days after anthesis 25% of the activity resided in the coat and 75% in the endosperm. The disappearance of the enzyme can only partly be explained by the decline of the grain coat.

(3) *Utilization of γ-Aminobutyric Acid by Wheat Seedlings.*—Feeding experiments and enzyme tests were carried out to investigate the utilization of γ-aminobutyric acid (γ-AB) by wheat seedlings.

In the feeding experiments, embryos were excised from the grain 20–24 hr after soaking, explanted on a basal medium to which different nitrogen sources were added, and incubated at 25°C in the dark mostly for 120 hr. Growth in length and nitrogen content (insoluble, and once, also total) were measured.

γ-AB nitrogen was utilized for protein synthesis. The optimal concentration was 6.0mM. The seedlings were tolerant to 12.0mM γ-AB, the only ill-effect of that concentration being a retardation of root growth.

Different amino acids tested at nitrogen-equivalent concentration produced the following sequence in insoluble nitrogen content per seedling: control = L-α, γ-diaminobutyric acid < LD-α-aminobutyric acid = γ-AB < L-proline < L-alanine = L-glutamic acid < L-asparagine = L-glutamine = nitrate.

Growth in length of the first leaf was on all occasions stimulated by γ-AB, but with one exception root growth was not.

Extracts of roots of 2- and 3-day-old intact seedlings had about 2.5 times the glutamic acid decarboxylase activity (per seedling) of that of shoot extracts; on a protein basis the ratio became more than 6.

No γ-AB–glutamic acid transaminase could be shown in root and shoot extracts, even after attempts to induce the enzyme, but alanine–glutamic acid transaminase activity was high in similar extracts. Neither was any evidence found for the presence of γ-AB oxidase in the seedlings.

(4) *Seedling Growth in Wheat.*—Growth of wheat in a constant environment was studied for a period of 21 days. The central feature of this work is the description of initiation and subsequent growth of each successive leaf, or leaf primordium as it is then called. This details for the first time a quantitative picture of the pattern of growth at the shoot apex, linked with an equally detailed study of the dry weight changes in all parts of the primary shoot.

Early growth of each leaf primordium is exponential, but the exponent decreases with leaf number in a rather discontinuous manner. Following the exponential phase, the rates rise to maximum and then fall asymptotically to zero. Relative growth rates for leaves and roots are particularly high while seed reserves are available. With time, there is a progressive change in dominance from leaf growth to stem growth.

(5) *Inflorescence Initiation in* Lolium temulentum.—By keeping some leaves of mature plants of *L. temulentum* in short-day conditions, while other leaves were simultaneously exposed to 1 long day, and by removing either the short- or long-day leaves at intervals, it has been shown that a transmissible stimulus to infloresence initiation is produced in the long-day leaves, and a transmissible inhibitor in short-day leaves. These substances are competitive, and the outcome of their interaction depends not only on day length but also on temperature and on the spectral composition of the light.

The light dependence of the inhibitory and promotive processes is currently under investigation. It has been found that the dark inhibitory process is markedly affected by the spectral composition of light during the preceding photoperiod, and that the promotive process can occur when only red or far-red light is given during a long day, but is more rapid when the red and far-red light are given simultaneously.

(6) *Dependence of Photoperiodic Perception on Level of Insertion of Foliar Organ.*—In *Anagallis arvensis* L. subspecies *foemina* (Mill) Schinz and Thell (blue pimpernell) flower initiation occurs at the third or fourth node above an appropriately sized single-leaf pair exposed to two 20 hr days at 20°C. There is only a brief period during which the long-day exposure will initiate flowers at a specified node — if given earlier the primordial meristem concerned is either absent or too small, if given later it is already vegetatively determined.

When only the fully assimilatory cotyledons are so exposed (at any stage from emergence to maturity) flower initiation does not occur. This may be due to (i) absence of a labile meristem, (ii) failure of cotyledons to perceive the long-day stimulus, (iii) subsequent failure to elaborate a floral stimulus, (iv) non-transport of stimulus to a meristem. The second possibility may be discounted since the expansion of these cotyledons has been demonstrated to be controlled by their exposure to red and far-red radiation. Unequivocal evidence to decide between the three remaining possibilities is lacking but results from defoliation and transport experiment render (i) and (iv) less likely.

On the primary axis later-formed leaves are less effective in promoting flower initiation than earlier leaves at a comparable size, and leaves on secondary axes inserted at a higher level are less effective than those on lower axes. These apparent age effects on photoperiodic sensitivity do not conform with evidence from other long-day plants.

8. Biochemistry

(i) *Structure and Properties of Plant Photoreceptors*

Partial purification of a protochlorophyll holochrome has been achieved.

Studies on the conversion of the protochlorophyll to chlorophyll suggest that a collision process between protein molecules and hydrogen donors is not involved but that the hydrogen donor is intimately associated with the protochlorophyll-protein complex.

(ii) *Porphyrin and Haem Synthesis in Legume Root Nodules*

Because of the known correlation between the haemoglobin content of certain root nodules and their effectiveness in nitrogen fixation, haem and porphyrin biosynthesis in effective and ineffective nodules of soybean have been studied.

Incubation of nodule *breis* with ^{14}C-labelled glycine under a variety of conditions failed to show any incorporation into haemoglobin while experiments with δ-aminolaevlulinic acid led to variable results.

(iii) *Coproporphyrinogen Oxidative Decarboxylase*

Two major gaps still exist in knowledge of the biosynthetic pathway from glycine to haem. The first is the formation of uroporphyrinogen III from porphobilinogen and the second is the formation of protoporphyrin from coproporphyrinogen III. The latter step, the decarboxylation and oxidation of two propionic acid groups to vinyl groups, is being studied.

The enzyme has been obtained in soluble form from an acetone-dried powder of bovine liver mitochondria. With the aid of a quantitative assay which has been developed, the soluble extract is being characterized, with respect to heat stability, pH optimum, and substrate specificity.

Current work is aimed at further purification of this enzyme.

(iv) *Pseudouroporphyrin*

This porphyrin had previously been found in biosynthetic studies using chicken erythrocyte preparations. Further work, in part with plants, furnished more evidence that it may be derived from an important intermediate in porphyrin biosynthesis.

(v) *Theoretical Chemistry of Porphyrins and Metalloporphyrins*

As a contribution towards understanding the behaviour and characteristics of the natural haemoproteins, some of the physico-chemical properties of porphyrins and metalloporphyrins have been systematized. Data from the literature, and material from new studies, were used. It was shown that the relationships between structure, spectrum, and redox-potential are systematic, and theoretically predictable, throughout all the model porphyrins and metalloporphyrins available.

It became clear that among the further complexes of haems (the "haemochromes"), the models previously studied have little relevance to the haemoproteins, for which they should provide structural models. Model haemochromes were found with spectroscopic properties strikingly similar to those of the cytochromes *a*, *b*, and *c*.

(vi) *Analytical Methods for Porphyrins and Chlorophylls*

A counter-current distribution method has been worked out for the separation and purification, in bulk, of chlorophylls *a* and *b*.

Paper-chromatographic methods have been developed which permit the identification in mixtures, of protochlorophyll, chlorophylls *a* and *b*, and a variety of porphyrins, and also one which permits the identification of porphyrins in incubation mixtures containing blood or chlorophyll, without prior purification of the pigments by extraction.

A column-chromatographic method has been found for the separation of chloride and perchlorate in mixtures, and is being developed systematically.

(vii) *Physico-chemical Studies on Tetrapyrrole Pigments*

The ionization, coordination, and spectroscopic behaviour of porphyrin and chlorophyll derivatives have been further studied, to correlate these physico-chemical properties with the many diverse biological phenomena such as oxygen transport, electron transport, nitrogen fixation, and photosynthesis which are associated with the tetrapyrrole pigments in animals and plants.

Studies on incorporation of metal ions into porphyrins revealed some surprising catalytic effects. Thus reaction between cupric ions (Cu^{++}) and a porphyrin ester in aqueous solution can be catalysed 500,000-fold in the presence of an anionic detergent and an equimolar (with respect to Cu^{++}) concentration of a specific chelating agent (oxine), yet completely inhibited if the oxine/Cu^{++} mole ratio is increased from one- to twofold. Interest in such a system centres about its obvious analogy to enzyme catalysis. Its possibilities as a model for haem iron incorporation are being explored.

(viii) *Role of "Indoleacetic Acid Oxidase-Peroxidase" in Growth*

The question is raised whether the indoleacetic acid (IAA) oxidase-peroxidase as studied in tissue macerates functions in intact cells to control the IAA level. Treatments (blue light and 2,4-dichlorphenol) known to increase IAA destruction in tissue macerates several-fold were applied to the elongating zone of pea roots, the growth of which was limited by supra-optimal IAA concentrations. No corresponding decrease of growth inhibition was obtained. The IAA oxidase-peroxidase, as constituted in macerates, appears to act upon the IAA present at the growth receptor in the cells of this tissue.

(ix) *Cultivation of Isolated Tissue from Stelar Parenchyma*

Treatment of isolated flax roots with indoleacetic acid causes proliferation of the pericycle. By maceration, this proliferation can be maintained independent of the root. The growth of the resultant callus depends upon the concentration of added coconut milk or kinetin; auxin is not required. Growth is enhanced by the addition of yeast extract or phosphate to the medium.

Lignified cells and root primordia arise spontaneously in some pieces of callus. The root primordia frequently have their origins adjacent to lignified cells.

The potential use of this callus in studying cellular differentiation is stressed.

(x) *A Kinin from Apple Fruitlets*

As was reported previously, extracts from apple fruitlets in the cell-division phase of growth cause initiation of cell division in mature cells of certain tissues. Similar activity has been detected in extracts of fruitlets of other species and other plant tissues undergoing cell division.

During the year, some three-quarters of a ton of apple fruitlets was collected, and an aqueous-alcohol extract, in which the kinin is stable, was made and concentrated. Studies on the isolation of the kinin, which is a relatively small molecule, are in progress. In addition, the activity of the kinin on a variety of tissues is being studied, quantitative bioassay methods for the kinin are being sought, and other physiologically active substances in the concentrate are being investigated.

(xi) *Pisatin, an Antifungal Substance Produced in Peas*

As part of a study of the chemical basis of natural disease resistance in plants, isolation and characterization have been undertaken of the antifungal substance produced within the endocarp of pea pods (*Pisum sativum*) following inoculation with *Sclerotinia fructicola*.

A substance to which the name pisatin has been given has now been crystallized (*see* Section 4(*c*)(i)(2) of this chapter). Under standard conditions it inhibits the germination of *S. fructicola* at a concentration of 10^{-4}M. The average concentration of pisatin in diffusates obtained 24 hr after inoculation of pea pods with the fungus is about 2.7×10^{-4}M.

Structural studies indicate that pisatin is probably related to 3-hydroxypterocarpine.

(xii) *Tobacco Mosaic Virus* (TMV)

Attempts to isolate an infective, free ribonucleic acid (RNA) fraction from TMV-infected tobacco leaves using carboxymethyl-cellulose (CM-cellulose) have been unsuccessful. When infective RNA, prepared from TMV, is ground with healthy tobacco leaves and CM-cellulose, more than 80% of it is irreversibly adsorbed to the buffer-insoluble residue.

The procedure developed by Schramm has been followed and his observation has been confirmed that the content of infective, free RNA within the tobacco leaf reaches a maximum approximately 30 hr after inoculation of the plant with TMV. It was found also that an infective RNA fraction occurs in the TMV-infected, local-lesion host *N. glutinosa*.

(xiii) *Changes in Phosphate Solubility during Microbial Decomposition of Organic Matter*

The purpose of this study is to define factors governing availability of soil phosphorus to plants, and to find new approaches to the utilization of native soil phosphorus or to the efficient use of applied phosphate.

Reduction of iron compounds may play an important part in phosphate availability in soils. Processes leading to the solution of ferric phosphate during anaerobic microbial decomposition of plant material are being studied. Production of a reducing environment appears more important than production of iron-complexing organic acids. Confirmation of this is being sought.

(xiv) *Origin of Soil Organic Phosphorus*

Under grazing conditions much phosphorus applied as fertilizer is converted to less available organic forms. The contribution of sheep faeces to this conversion is being investigated.

It has been found that considerable amounts of sparingly water-soluble inorganic phosphate is voided by sheep each year, as well as significant amounts of organic phosphorus. Availability of phosphorus was related closely to the acid-soluble inorganic phosphate content of faeces. Organic phosphorus resisted microbial decomposition to inorganic phosphorus under aerobic conditions and may thus contribute directly to the soil organic phosphorus reserves.

(xv) *Location of Membrane Resistance in* Nitella

There is a marked discrepancy between the electric resistance of the tonoplast as predicted from measurements of ionic fluxes and the resistance measured by the microelectrode method; the latter is some 200 times lower. Accordingly experiments have been done in which the whole cell resistance was measured, firstly, by the microelectrode method previously used, and secondly, by an external contact method which did not involve risk of injuring membranes by puncture. Agreement was achieved between the two methods, and it was concluded that the microelectrode method was trustworthy. The discrepancy mentioned is therefore still unexplained, and the following investigation is related to this.

(xvi) *Charge Carriers in Tonoplast of* Chara *and* Nitella

In studies in cooperation with the Plant Physiology Unit, Sydney, it seemed that one of the major ions crossing the tonoplast might do so in such a way that its response to a small change of external conditions (e.g. an electric current) would be a very large change in its flux. The aim was to discover whether any of the major ions carried an applied electric current across the tonoplast. A positive result would have provided valuable evidence for the nature of the ion-carrying mechanism of the tonoplast. Radioactive tracer experiments were performed on the influx and efflux of sodium ions across the tonoplast of *Chara australis*, in the presence of an applied electric current. Sodium ions carried at most a few per cent. of the current. This work will be continued when radioactive potassium is available.

(xvii) *Resting Potential and Resistance in* Chara *Cells*

Resting potential and resistance of these cells had been shown to be located at the outer membrane (plasmalemma). Resting potential has been described as a KCl diffusion potential, but direct experiments to confirm this are hampered by the cell wall, which behaves as a Donnan system with a high potential in series with the plasmalemma potential. In collaboration with the Division of Food Preservation (*see* Chapter 20, Section 9(i)), an experimental procedure was designed which allowed experiments to be made on membrane potential without interference from wall potential. Measurements were then made of membrane potential and resistance as affected by concentrations of ions in the medium bathing the cell. Results agreed satisfactorily with the predictions of the "Constant Field" membrane equation. They confirm that, under the conditions of the experiments, the potential and resistance of the cell are determined by the passive diffusion of potassium and sodium ions across the membrane. The permeabilities of these two ions as deduced from these measurements agreed with the values deduced from flux measurements. It is therefore not necessary to postulate large exchange fluxes of these ions across the plasmalemma, but it is necessary to postulate an active "sodium pump" at the plasmalemma to account for the steady state of the cell.

(xviii) *Injury and Herbicides*

(1) *Cold Hardiness*.—In collaboration with the Genetics Section, a study has been made of the inheritance of cold hardiness in lucerne, using the low frequency electric resistance of the tissue as the criterion. Behaviour of a cross can be predicted from the behaviour of its parents.

(2) *Injury*.—Poisons such as 2,4-D initially cause an increase in low frequency resistance, after which the resistance falls to a low value. With such a poison it has been found that equivalent series capacitance at first decreases, then becomes infinite. Accordingly, by using series capacitance measurements as well, it is possible to determine if injury has been caused, even though the resistance values are the same as those in uninjured tissues.

Studies have been made in pea root sections with the hydrazine salt of 2,4-D, originally developed for the control of mistletoe. Hydrazine at low concentrations is an active plant poison, and has a synergistic reaction with 2,4-D.

(3) *Mistletoe Control*.—Three further seasonal trials have been laid down, in collaboration with the Forestry and Timber Bureau. From the interim observations 2,4-D, its hydrazine salt, 2,4-D plus an organic borate, and "Trysben" (2,3,6-trichlorobenzoic acid) are giving the best results.

(4) *Translocation Studies*.—It has been shown how the age of skeleton-weed influences the downward translocation of substances applied to the leaves. This translocation is being correlated with the sugar content and metabolic behaviour of the leaves.

9. Agricultural Physics

(i) *Mathematics of Diffusion*

(1) *Exact Solution of the Concentration-Dependent Diffusion Equation.*—Water movement in unsaturated porous materials such as soils may be described as concentration-dependent diffusion. Hitherto, mathematical analysis of the problems arising in this connexion required numerical methods. A general analytical method was developed for solving unsteady one-dimensional non-linear diffusion problems. This work involves use of an inverse form of error function. This function was investigated and tabulated.

(2) *Concentration-Dependent Diffusion in Cylindrically and Spherically Symmetrical Regions.*—A basic study, involving development of rapid and accurate numerical methods, is complete, but further detailed work is required before the work can be published.

(3) *Diffusion from a Well-Stirred Reservoir.*—A detailed mathematical investigation of the phenomenon of diffusion from a well-stirred reservoir has been made. This relates to an experimental method of studying gaseous diffusion in the soil being developed by Dr. D. S. McIntyre.

(ii) *Soil-Water Studies*

(1) *The Influence of Temperature on Soil Moisture Tension.*—Theory has been developed which is based on the temperature dependence of the volume of entrapped air, the specific volume of water, and the surface tension of water held in a soil and on the external air pressure dependence of the volume of entrapped air. This theory is described in a paper which has been accepted for publication. Extensions to the theory have been made to include the temperature dependence of the solubility of air in water. Various effects contributing to tension changes with temperature are commonly of the same order of magnitude. As tension will change with air pressure the pressure plate and suction plate methods of moisture extraction will commonly yield different results.

Observations agree broadly with theory but a critical test has awaited the solution of certain instrumental difficulties.

(2) *Water-table as Affected by Air Pressure.*—A theory of water-table fluctuation due to changes in atmospheric pressure has been developed. Predictions of the theory were confirmed experimentally. Both theory and experiment are described in a paper which has been submitted for publication.

(3) *Moisture Content–Tension and Moisture Content–Conductivity Relations of Soils in the Feld.*—Apparatus to permit corrections for end effects and to eliminate edge effects in an *in vitro* determination of hydraulic conductivity has been designed. Controlled pressure apparatus has been set up for a series of suction plates.

(4) *Absorption and Infiltration.*—Studies of the early stages of absorption and infiltration, and of the viscous dissipation of energy during these phenomena, have now been published. Absolute thermodynamic functions are useful in connexion with an energy balance method of investigating viscous dissipation.

(5) *Mass Flow of Air and Evaporation from Soil.* Evaporation of water from bare soil may be influenced by mass flow of air through the soil. This may explain some peculiar experimental results to be found in the literature. A theoretical analysis has been carried out which suggests that mass flow could arise from microvariations in air pressure at the soil surface. Further theoretical studies are proposed and will be integrated with a parallel experimental program involving model studies in a wind tunnel. Experimental equipment is in course of development.

(iii) *Micrometeorology*

(1) *Theory of Local Advection.*—The general mathematical basis of this study of the simultaneous transfer of heat and moisture in the lower atmosphere under conditions of horizontal heterogeneity has been published during the year. Detailed calculations relating to advective fog formation on winter nights have been made. Work remains to be done on applying the theory to specific problems.

(2) *Experimental Studies of Local Advection.*—Experimental studies of the theory of local advection ideally require an extensive upwind dry surface separated from a downwind wet surface by a clear-cut leading edge. Such a set-up has been constructed at Canberra airport. The upwind surface consists of 350 m of concrete tarmac oriented in the prevailing wind direction. The downwind surface consists of a graded area, sown to grass and watered as required.

The mobile micrometeorological recorder and integrator described below is being used to observe the fine structure of the temperature and humidity fields at and immediately downwind of the leading edge. Observations in this region will provide the most precise tests of the theory of local advection.

(3) *Mobile Micrometeorological Recorder and Integrator.*—A mobile micrometeorological recorder and integrator has been constructed and is in active use. The system enables temperature and humidity profiles in the vertical and horizontal to be determined with equal resolution. Data for twenty points can be obtained at the one time. Results are presented on electromagnetic counters and automatically averaged at pre-determined times.

(4) *Analysis of Turbulent Boundary Layer.*—The analysis depends on a novel "mixing-length" model of turbulence. The work on the case of zero pressure gradient has been published during the year. The case of non-zero pressure gradient is amenable to analysis by the same methods.

(5) *Atmospheric Diffusion and Natural Radon.*—Recent work attempting to relate the diurnal cycle of natural radon concentration near the ground to the diurnal cycle of intensity of atmospheric diffusion is quantitatively incorrect, since certain neglected terms in the diffusion equation were much larger than those retained.

(6) *The Energy Balance of Healthy and Diseased Tobacco Leaves.*—Nocturnal water loss of diseased tobacco leaves greatly exceeds that from healthy ones. A detailed study has been made of the nocturnal temperature profiles in the first centimetre above the surfaces of healthy and diseased leaves. The major

contribution to the extra energy of the diseased leaves is of metabolic origin. More detailed investigation is planned.

(7) *Microenvironment of Tobacco in Relation to Blue Mould*.—Laboratory observation and field experience indicate the broad dependence of blue mould incidence on meteorological conditions. But the patchiness of the incidence suggests that microenvironmental conditions related to the site or to cultural practices may be important. This investigation has been directed towards evaluating the magnitude of differences between environments and their effect on disease development. Attention was also given to the possibility of forecasting favourable conditions for blue mould development as part of a chemical control procedure.

The mobile micrometeorological unit described above was used for these purposes in the Ovens Valley during 1959–January 1960. Information on the conditions within tobacco crops was collected and the pattern of disease development was traced simultaneously. Analysis of the data is not yet complete.

(8) *Automatic Measurement of Soil Temperature Profiles on North and South Slopes*.—Equipment has been developed and assembled which will enable soil temperature profiles on the two slopes to be recorded and compared. This project is related to the interest of agronomists in the problem of mid-winter pasture production.

10. Ecology

(*a*) *Plant Sociology*

(i) *Exotic Species*

The interrelationships of plant species, particularly those of weed communities, are being investigated. Studies of the possible influences of one germinating species on the germination of another have revealed some interesting effects of carbon dioxide on germination. However, the main emphasis of this work is on the mutual interactions of species growing together under different conditions of nutrient supply. The objective is to study the physiology of plants growing in communities, and the shift in their physiological optima in the presence of other species under different environmental conditions.

A study of the interactions of a number of alien species at different levels of nitrogen and calcium is being made. The project includes investigations of competition between useful economic plants and weeds. An experiment on the nature of competition between St. John's wort and subterranean clover has been completed.

(ii) *Native Species*

(1) *Soil Calcium in Relation to Distribution of Eucalypts*.—Studies of the nutrient status of the soils of some plant communities occurring on the Southern Tablelands of New South Wales have indicated that the level of exchangeable calcium in the soil may be one factor influencing the distribution of *Eucalyptus rossii* and *E. melliodora*. It has also been shown that the development of a particular community will depend in part on the presence or absence of interspecific competition at the time of colonization of a bare area. A study of the effects

of varying levels of soil calcium on interspecific competition between *E. rossii* and *E. melliodora* supports the hypothesis that soil calcium is an important factor in the distribution of these two species. The operative factor is probably the degree of calcium saturation, rather than the absolute amount of calcium on the exchange complex.

(2) *Soil Phosphorus in Relation to the Distribution of Eucalypts.*—Study of the growth of *E. melliodora* and *E. rossii* in pure and mixed stands at different levels of phosphorus has recently been completed. Interesting interactions between species and phosphorus level have been demonstrated where the two species are grown in competition, but the full significance of the results is not yet clear.

(*b*) *Alpine Ecology*

(1) *Catchment Hydrology.*—These investigations are designed to seek an understanding of successional relationships of the various high-mountain plant communities, and to evaluate this significance in relation to surface run-off and soil loss, and the accumulation, storage, yield, and use of water.

Experimental results indicate that considerable improvement in catchment performance would result from management practices which encourage regeneration of natural communities. Reafforestation would materially improve the amount and distribution of snow water yield. The effect of trees at high altitudes in straining out water from rain clouds moving through them has been studied, and increases of up to 30% in the rainfall under trees, compared with neighbouring treeless areas, have been demonstrated. In badly eroded areas at high altitude, regeneration of native communities is very slow, and may well be impracticable. In such areas the use of introduced species for catchment improvement is being examined.

(2) *Permanent Reference Areas.*—Permanent reference areas have been established to measure changes in the vegetation following the cessation of grazing above 4500 ft, and to measure cyclical changes in undisturbed plant communities.

(*c*) *Rain-Forest Ecology*

Current investigations are concerned chiefly with subtropical rain-forests of southern Queensland and northern New South Wales. Following the general reconnaissance survey of the rain-forests of eastern Australia, a more detailed survey of the subtropical rain-forests of south-eastern Queensland has been completed. These studies have emphasized the importance of the edaphic factor in rain-forest distribution. A system of rain-forest classification based on structural characteristics and leaf size has been proposed.

Studies of nutrient circulation and immobilization in rain-forest, in conjunction with a knowledge of the place of the edaphic factor in rain-forest distribution, leads to an understanding of the disastrous consequences of clearing and land exploitation in many areas. The application of known facts and principles to land use policy would prevent such effects, and at the same time maintain valuable stands of timber. The hydrological aspects of rain-forest must also be evaluated, especially in relation to the prevention of flash flooding and erosion.

Studies of the regeneration of hoop pine and *Grevillea robusta* have been continued. The possibility that regeneration of *G. robusta* may be inhibited by the presence of toxic substances in the litter has been investigated, but it has become apparent that the problem is complex, and that other factors are involved.

(*d*) *Arid Zone Ecology*

Soil studies in the south-eastern portion of the Australian Arid Zone have indicated that alternation of pluvial and non-pluvial periods during the Tertiary-Quaternary resulted in periodicity of soil formation and landscape development. Soil formation occurred during the pluvial periods when the landscape was protected from erosion deposition by a well-developed vegetative cover. Varying amounts of erosion and deposition occurred during the non-pluvial periods. The Tertiary erosional periods were characterized by water erosion-deposition and major changes of land form. The desertic climate of the Quaternary erosional periods resulted in widespread wind erosion. Soils of four different ages have been recognized. All the soils in the region are paleosols.

(*e*) *Pasture Investigations*

(1) *Special Purpose Pastures.*—Animal production from pasture is limited by those periods during which pasture growth does not keep pace with animal requirements. In southern Australia, pasture growth is limited by low temperatures in winter and by high temperatures and water stress in summer. Some levelling of the curve of pasture production would be expected by the use of species which are better adapted for winter or summer growth than are those in common use. A grazing trial in which a number of strains of perennial grasses are being compared for winter and summer production has given promising results in terms of wool production and liveweight gains. A Mediterranean strain of cocksfoot has proved superior to *Phalaris* and other grasses for winter production, while *Bromus inermis* and Oregon fescue appear to be the most promising grasses of those tested for summer grazing.

This study is to be continued at the Ginninderra Field Station, where different aspects are expected to provide more favourable conditions for the growth of summer and winter grasses.

(2) *Effect of Gibberellic Acid on Winter Production of a* Phalaris–*Subterranean Clover Pasture.*—The possibility of increasing winter pasture production by the use of growth stimulators is being investigated. Winter production of *Phalaris* and subterranean clover is increased by spraying with gibberellic acid, but this is followed by a reduction of spring growth. Total production of treated and control plots is the same. Increased winter growth of the pasture species does not result in any increase in animal production.

(3) *Effect of Sheep Grazing on the Vegetation of Temperate Australia.*—A broad survey is being made of changes in plant communities which have occurred in southern Australia as a result of the utilization of the land for sheep raising. Data collected over the last 10 years are in process of collation and analysis.

(4) *Pasture Legumes.*—In the semi-arid areas of New South Wales, various species of *Medicago* are valuable components of the pastures. However, the spiny burrs of certain species and varieties are largely responsible for burr contamination in the Australian wool clip. Current studies aim to obtain a better understanding of the distribution and ecological requirements of the naturalized species, and at replacing those species and strains with a spiny burr by others with non-spiny burr. It has been shown that *Medicago minima* can be replaced by *M. tribuloides* on the black earths and brown acid soils. A study of the distribution of *Medicago* spp. in relation to the major soil groups has been made in the Macquarie region.

(5) *Effect of Temperature Regime on Strains of* Phalaris tuberosa.—Temperature tolerances (using controlled temperature glass-houses) have been examined in young plants of 56 strains of *Phalaris tuberosa.* Strains which are tolerant of low temperatures can be selected, but at the same time such a study indicates which strains are likely to show a better overall performance than commercial *Phalaris.* Four strains have been selected for field trials in conjunction with *Trifolium subterraneum.*

(*f*) *Weed Ecology*

(i) *Survey of Alien Plants in Southern Australia*

A survey is being made of naturalized plants in Australia and of the ecological factors governing their occurrence both in Australia and in their countries of origin. Particular attention is being paid to species of importance as weeds in Australia. Land use and disturbance under grazing are important factors in the occurrence of naturalized alien species. The study includes factors other than biotic, and attention is being paid to the climatic factor, especially temperature. Data obtained from naturally occurring alien plant communities are being tested experimentally in field plots.

(ii) *Weeds of Arable Land*

(1) *Skeleton-Weed.*—Experiments on the effects of competition between skeleton-weed and subterranean clover have been concluded. Clover leys will reduce skeleton-weed density to a level at which the weed will not compete strongly with subsequent wheat crops. Moreover, the increase in nitrogen levels under clover results in much higher cereal yields during the cropping phase.

(2) *Soursob* (Oxalis pes-caprae).—Soursob is an important weed of grazed areas in certain parts of South Australia, chiefly because it is poisonous to stock. Current experiments, conducted in cooperation with the South Australian Department of Agriculture, aim to develop a combined chemical and cultivation program which will enable dense infestations to be reduced to insignificant proportions.

(iii) *Weeds of Pasture*

(1) *Serrated Tussock and Bracken.*—Control of pasture weeds where conditions are unsuitable for the use of ground machinery presents special problems, since direct attack and pasture improvement are both hampered. The object of the

present work is to determine the effects of certain feasible practices on control of serrated tussock and bracken under conditions where cultivation is impracticable.

Current investigations aim at weakening the stand of the weed by means of suitable chemical treatment so that the establishment of competing pasture species may be achieved. Results to date suggest that some suppression of serrated tussock can be achieved following establishment of subterranean clover. Attempts to establish pasture species in stands of bracken following reduction in frond density by chemical treatment have so far been unsuccessful.

(2) *Thistles.*—Work on this project has been chiefly a study of variegated thistle (*Silybum marianum*) and Scotch thistle (*Onopordum spp.*). In a preliminary study of four thistles (*Carduus pycrocephalus, Cirsium vulgare, Onopordum acanthium,* and *Silybum marianum*) it has been found that these species occur on soils of higher total nitrogen and exchangeable bases than the soils of neighbouring non-infested areas. However, little is known of the ecological requirements of thistles, and field and glass-house studies have been designed to throw light on some aspects of the problem. The effects of various perennial pasture species on germination, establishment, and growth of thistles, and the role of weedicides for suppression of thistle during the establishment phase of the pasture species, are being studied. Lucerne and *Phalaris* appear to markedly suppress variegated thistle.

(*g*) *Tree Physiology*

Effects of 16 combinations of day/night temperature on the growth of a number of species of *Eucalyptus* have been examined. Day length does not determine the cessation of growth of eucalypts during winter, the predominant controlling factor (assuming moisture is adequate) being temperature.

The effects of gibberellic acid on a range of woody perennials have been investigated, special attention being paid to eucalypts. In general, responses of eucalypts to gibberellic acid under short days are greater than under long days. Anatomical studies have demonstrated a significant increase in fibre and vessel element length, a result of interest to the paper trade in view of the importance of fibre length in the mechanical properties of paper.

11. Animal Husbandry

(i) *Pasture Utilization*

Investigations to establish factors influencing the nutrition and productivity of the grazing animal, and to measure the effect of the animal on the pasture, have been continued. Errors in measurement associated with this work have emphasized the need for the development of new techniques.

Greater seasonal variation in wool production has been found in sheep grazing on subterranean clover with volunteer annual grasses than on a sown pasture of *Phalaris* and subterranean clover, particularly at high stocking levels. On both types of pasture, differences in wool quality at different stocking levels did not affect prices realized.

On a *Phalaris*–subterranean clover pasture stocked at 4 ewes per acre, neither ewe nor lamb nutrition was influenced by management practices. However, at a higher stocking rate of 7 ewes per acre, weight gains in lambs were increased by having grazing lucerne available when pastures were drying off in early summer.

Supplementation of dry summer pasture has been investigated as a means of reducing weight losses of sheep. In a grazing trial, liveweight losses were the same on dry *Phalaris*–subterranean clover pasture as on similar pasture sprayed with molasses and urea. Weight losses were not affected by giving sheep access to green lucerne either 1 day per week or 1 hr per day.

(ii) *Supplementary Feeding*

(1) *Fodder Conservation*.—On the Southern Tablelands of New South Wales, carrying capacity is limited by pasture productivity during winter and summer. Conservation of excess pasture in the spring, and feeding back during periods of shortage, might be expected to increase the food supply during critical periods, achieve greater efficiency of utilization of the pasture, and permit the carrying of larger numbers of stock. Experiments designed to determine the value of fodder conservation on *Phalaris*–subterranean clover pasture have so far indicated that its chief value may be in the prevention of deaths during drought periods. At relatively low stocking rates, little advantage was gained from winter and summer feeding of conserved fodder during normal years.

(2) *Oats as Winter Green Feed*.—Oats was oversown into a *Phalaris*–subterranean clover pasture after a minimum of cultivation, one-third of the area being treated annually. Breeding ewes (Merino) were run at 4–5 ewes per acre and compared with similar flocks grazing pasture without supplementary oats. Flocks having access to winter oats showed no increase in percentage of lambs marked or lamb weight at weaning, and no increase in liveweight or wool production in the ewes. Cropping reduced the proportion of *Phalaris* in the pasture, and increased the proportion of weeds.

(iii) *Animal Behaviour*

(1) *Grazing Behaviour*.—Relationships between pasture quality and ruminating time, and between pasture availability and grazing time have been established. Seasonal changes in the pattern of grazing behaviour have also been studied.

(2) *Social Facilitation*.—Distinct differences in social facilitation appear to exist between Merino and crossbred sheep. The degree of gregariousness developed within a breed has been found to influence both pasture utilization and animal production.

(3) *Diet Selection*.—Rearing lambs on different herbage species considerably influenced their ability to utilize those species to which they had become accustomed up to the age of 4 months, but has little influence after 5 months.

Different preferences by individual animals have produced marked differences in the botanical composition of an originally uniform pasture grazed by individual sheep.

Sight appears to have little effect on diet selection. Control and blinkered sheep have shown no difference in weight changes. Intake and diet quality have been lower for blinkered sheep only on dry *Phalaris* pasture.

Diet selection has not been affected by severing the mental branches of the fifth cranial nerve which controls the sensory nerve endings in the lower jaw.

Ruminating time, intake, and liveweight gain have been impaired temporarily following an operation to remove the sense of taste from the back one-third of the tongue, but the quality of the diet was not affected.

Preliminary studies have been made with oesophageal fistulated sheep grazing on *Phalaris*–subterranean clover pasture, and this work will be expanded. Individual sheep vary widely in the plant species selected, but there is little difference in nitrogen content of the feed selected by different animals. As the pasture dries out in late spring and early summer, there is a rapid decrease in nitrogen content of the feed selected, corresponding with the general decrease in nitrogen content of the pasture at this stage. The nitrogen content of the feed selected is always higher than the mean value for the available feed at any time.

12. Pasture Investigations (at Armidale, N.S.W.)

(*a*) *Soil Fertility*

(i) *Sulphur Studies*

Extensive field experiments have established the existence of widespread and acute sulphur deficiency. Recent work has been concerned with detailed studies of sulphur techniques for estimation, mineralization from soil organic matter, pathway of transformations from organic to inorganic forms, and changes in status of soil sulphur of consequence in pot culture work.

(1) *Sulphur Status of Eastern Australian Soils.*—Twenty-four soils were studied in pot cultures and responses to added sulphur measured. New England soils were all deficient in sulphur as measured by the growth of *Phalaris tuberosa* over a 14 months' period. A coastal krasnozem was not deficient, but a "wallum" soil was markedly so, in spite of its proximity to the seaboard. Soils from more arid western areas were less deficient than New England soils.

(2) *Comparison of Procedures for Estimating Sulphur Status of Soils.*—Of a number of chemical procedures investigated, that which extracted amounts of sulphur showing the most satisfactory correlation with sulphur-supplying capacity of the soils (as measured by plant growth) was an extraction with KH_2PO_4 solution containing 500 p.p.m. phosphorus. The superiority of this procedure over the others tested probably lies in its ability to displace absorbed sulphate.

Sulphate extractable by the phosphate solution was found to be less after cropping by an amount that could not be entirely accounted for by uptake by the plants. The difference (uptake minus decrement), which represents the net mineralized sulphur, was small relative to the amounts of extractable sulphate initially present.

(3) *Oxidation of Cysteine to Sulphate in Soils.*—The pathway of oxidation of cysteine to sulphate was followed in soil contained in a perfusion unit.

The following compounds were identified in the system — cysteine sulphinic acid, cysteic acid, sulphite, and beta-hydroxypyruvic acid. Sulphide, which has often been postulated as an intermediate in the conversion of organic sulphur to sulphate, could not be detected in the system or in the gases emanating from it.

(4) *Mineralization of Sulphur from Soil Organic Matter.*—During extraction of soil with water some of soil organic matter appears to decompose to produce inorganic sulphate. Consequently the sulphate extracted by water is an over-estimate of available sulphur. This decomposition does not seem to occur when soil is extracted with a 0.15% solution of calcium chloride.

Drying soil also split inorganic sulphate from the soil organic sulphate. This sulphate was available to plants and can greatly affect interpretation of pot experiments. Even if two soils are dried at the same temperature the relative availability of sulphur may be no indication of the relative availability before drying.

Incubation of soil from an unfertilized native pasture did not result in mineralization of sulphur. This appeared due to low sulphur content of the decomposing fraction of the soil organic matter. Incubation of soil from a pasture growing clover and treated with superphosphate resulted in mineralization of sulphur.

(5) *Soil Sulphate Changes in the Presence and Absence of Plants.*—The relative intensity of immobilization and mineralization of sulphur in a range of soils was affected by the presence of growing plants. Where plants were growing, mineralization of the organic sulphur occurred with sulphate sulphur additions of 0, 4, 12, and 30 p.p.m. Sulphate was immobilized with additions at 108 p.p.m. of sulphate sulphur. In the absence of plants (with one exception) no net mineralization of organic sulphur occurred following additions of sulphate. Without added sulphate there was slight mineralization (less than with plants) in all soils except a lateritic krasnozem. The effect of growing plants may be due to the activities of rhizosphere microorganisms.

(ii) *Phosphorus Studies — Responses of* Phalaris tuberosa *to Dressings of Phosphorus*

Plant yield responses to current dressings of phosphorus were measured on four soil types that had received a range of past dressings of phosphate.

Podzolic soils with the lowest native phosphorus status showed the largest increases in available phosphorus per unit of phosphorus applied. A basaltic soil which was almost adequate in phosphorus for plant growth had the greatest capacity for "fixing" added phosphorus.

(iii) *Edaphic Studies — Relationship between Visible Soil Characters and Nutrient Status*

In cooperation with the Division of Soils an investigation has been undertaken (*see* Chapter 2, Section 8(*a*)(iii)) to explore the possibility of a relationship between characters normally used to define and classify virgin soils and their nutrient status. Nine great soil groups in the Ebor-Dorrigo-Tyringham area have been mapped and the soils from several areas within each great soil group examined for nutrient status in a pot experiment of the subtractive type.

Deficiencies of particular nutrients and the degree of deficiency were almost as large within groups as between groups. Deficiencies in some soils were more consistent than in others, e.g. phosphorus in the podzolic soils, and sulphur in the chocolate soils, but it was concluded that little useful information about the nutrient status of a particular great soil group could be inferred from the pattern in a single representative of that group.

An investigation commenced to examine the possibility of a relationship between environmental influences and differences in nutrient status within a single great soil group.

(iv) *Grazing Effects*

(1) *Return of Dung and Urine to Pasture.*—Observations on a large-scale fertilizer experiment with 10 years of grazing history indicate a low manurial value of dung and urine returned to pasture by the grazing animal.

Many aspects require investigation, such as the fate of nitrogen in the urine patch, availability of nutrients in the dung, and distribution of excreta of the grazed area and in "camps".

(2) *Return of Nutrients by Sheep being Fed Pasture.*—For every 1000 lb of feed consumed about 1 lb of sulphur is excreted in the faeces irrespective of the sulphur content of the feed. Most of the remainder of the ingested sulphur is excreted in the urine. Consequently, when the sulphur content of the feed is high, a large proportion is excreted in the urine, but, when it is low, urinary excretion is negligible. For fertilized pasture, urinary and faecal returns of sulphur are about equal.

From the literature it appears that about 7–8 lb of nitrogen are excreted in the faeces for each 1000 lb of feed consumed. Thus there would be a fairly constant N : S ratio in the faeces of 7–8 : 1.

(*b*) *Species Evaluation*

Pasture Species Grazing Experiment.—Greater production has been obtained from several simple grass–legume permanent pasture mixtures than from the most commonly used *Phalaris tuberosa*–*Trifolium repens* pasture. The outstanding pasture has been *Festuca arundinacea* var. Demeter–*T. repens*, which over the past 12 months has produced almost 30% greater liveweight gain by Merino sheep than has the *Phalaris*–white clover pasture. These results have been achieved only after the pastures have attained a relatively stable botanical composition with grass dominance.

(*c*) *Pasture Agronomy*

(i) *Seasonal Pasture Productivity*

Monthly yield samplings of a range of permanent pasture mixtures are carried out to obtain information on seasonal productivity. Over the last spring and summer period *Festuca arundinacea* var. Demeter pasture has consistently outyielded other pasture mixtures.

(ii) *Response of Lucerne to Boron*

Yield increases of lucerne on a chernozemic soil following applications of borax and lime and of borax alone have continued into the second year, although at a reduced level. The yield increase from borax and lime was 43% in the first year and 16% in the second.

On a solodic soil boron application increased the yield of lucerne in the first year by 64%. Use of lime on these soils depressed yield. Studies on this soil are continuing to check the above result and also to obtain information on the effects of different rates of application of boron.

(iii) *Lucerne Variety Testing*

As one of several centres where a range of lucerne varieties is being compared with Hunter River, seasonal yields have been measured over the past 2 years. During the summer the yield of the variety Du Puits has exceeded that of Hunter River by 21%. The yield of Hairy Peruvian variety during the winter exceeded Hunter River by 71%.

(iv) *Palatability of* Phalaris arundinacea

In a comparison of the relative palatability of *P. arundinacea* from five sources, marked differences have been recorded with grazing by sheep and cattle. Two lines from West Germany proved palatable. Two others, one from U.S.A. and one from Portugal, were unpalatable and one U.S.A. line was intermediate. There was evidence that unpalatability was registered through olefaction rather than gustation.

The material under test has proved to be different genetically. Chromosome counts have shown that with the palatable lines $2n = 28$, with the unpalatable line $2n = 42$, and for the line intermediate in palatability, $2n = 35$ or 28.

It is planned to investigate the absolute palatability of this material by intake measurements of sheep confined to plots of each line.

(v) *Improvement of Native Pastures*

(1) *Clover–Native Grass Balance.*—A problem encountered in improvement of native pastures by surface seeding with clovers (as in aerial pasture improvement) is the development of a marked dominance of the latter species. The effect on this dominance of limiting the amount of superphosphate applied is being investigated. Yields measured in the spring of the fourth year showed that white clover increased with increasing rates of application of superphosphate. Yields of native grasses were about the same at all rates of application so that total yields were higher with heavy rates.

(2) *Surface Seeding of Grasses.*—Clovers can be established readily where surface seeded into native pastures. Grasses cannot be established so readily and it is debatable whether it is better to sow both species directly into the native pasture or to delay the sowing of the grass for some years until after previously sown clover has built up the soil fertility. To test this, perennial ryegrass was

sown (with clover) into native pasture and sown (without clover) into native pasture that had been surface seeded with clover three years previously. Unfavourable seasonal conditions were responsible for a very poor establishment of the ryegrass but in the spring sowing into a previously established stand of clover gave better results. The experiment is continuing in the hope that the stand will improve and a better measure of the ryegrass present obtained next spring.

Spring sowings of short-rotation ryegrass and prairie grass were made into a dense stand of white clover which had been sprayed with (*A*) "Dalapon" and (*B*) "Amitrol". Yields of the grasses were considerably higher where the clover had been sprayed than where it had not. This small experiment was undertaken to investigate one method of obtaining a greater proportion of grass to clover as a bloat preventative.

(3) *Persistence of Perennial Ryegrass Varieties*.—Aerial sowing of pastures is the most widely used method of establishment in the New England region, and for this purpose ryegrass is the only grass which can be established with any success. However, the strains of perennial ryegrass commonly used will not persist satisfactorily, so a search for a more persistent strain is being made. A collection of 16 varieties is being tested for persistence and productivity at three localities.

(*d*) *Pasture Management and Utilization*

(i) *Native Pastures*

Studies of the management of native pastures have been concluded.

(ii) *Sown Pastures — Improvement of Winter Feed Supply*

Three measures potentially capable of providing increased winter forage are to be compared, using production of grazing sheep as the criterion. The measures are: use of nitrogen; use of an autumn rest period; and use of different species. At the same time the effect on utilization of the level of stocking will be studied.

While the pastures are being developed for the above experiment several subsidiary investigations have been carried out.

(1) *Soil Uniformity Trial*.—Before sowing the pastures the area was cropped with forage oats and the crop systematically sampled to provide information on the uniformity of the area. A very highly significant variation from plot to plot was observed, the yield from some areas being five times that of others. In collaboration with the Division of Soils the herbage and the soil at selected sites have been intensively sampled in an attempt to correlate the yield of oats with soil characteristics.

(2) *Rates and Times of Application of Nitrogen*.—To obtain information on best times and rates of application of nitrogen fertilizer to use later in the main experiment, these points have been investigated on pastures of Demeter fescue and *Phalaris tuberosa*. Nitrogen at three levels was applied at three dates in late autumn. The autumn and early winter period was dry and there was no appreciable response to nitrogen at the low rates applied (30 lb nitrogen per acre or less).

(3) *Autumn Resting.*—A small experiment was carried out to determine the effects of various periods of autumn rest on the winter and early spring production of Demeter fescue–white clover and *Phalaris*–white clover pastures. Analysis of results has not yet been completed.

(4) *Techniques.*—An apparatus has been developed to provide an objective estimate of the species composition of a cut sample of herbage without the need for time-consuming hand separation. It is based on the point quadrat. Comparisons so far undertaken have shown that it rapidly produces estimates of botanical composition similar to those obtained by subsequent hand separation of the same sample, provided the components are of about the same size.

(iii) *Winter Fodder Crops*

Another method of improving winter feed supply is to grow crops specially for this purpose. Various crops have been compared. Hungry Gap kale, giant rape, thousand head kale, thousand head kale (var. Canson), and oats (var. Algerian) were sampled on three occasions during the winter and the regrowth was sampled in September. The four cruciferous crops continued to grow through the winter but the oats did not grow well in late summer. However, the regrowth from the oats was greater than that from the other crops. The total yields at the September sampling ranged from 4500 to 2100 lb dry matter per acre and decreased in the following order: oats, giant rape, thousand head kale, Hungry Gap kale, and Canson kale.

(*e*) *Nodulation Studies*

(i) *Evaluation of Strains of* Rhizobium trifolii *Naturalized in the New England Region*

Field and laboratory tests were made of effectiveness and infective ability of 122 local isolations from subterranean clover. No strain was found consistently superior to standard commercial strains, but the level of effectiveness of the isolates was high, indicating selection for effectiveness by subterranean clover. Similarly infective ability of the isolates under field conditions was of a high order compared with standard strains, indicating selection from the naturalized population.

The chances of finding, among New England isolates, strains consistently infective on subterranean clover under local field conditions are greater than are the chances of finding useful infective strains among isolates from other areas.

(ii) *Effect of Legume Seed Components and of Treated Seed on* Rhizobium *Growth in Culture*

A water-soluble, heat-stable antibiotic is present in, and removable in active form from, the seed coat of subterranean clover. The amount of active antibiotic is much less in white clover or lucerne seed.

Nodulation responses to pelleting of subterranean clover seed found in previous experiments are probably due, at least in part, to physical separation, by the pellet, of seed coat and inoculum.

(iii) *Influence of Soil Fumigation on Nodulation Response of Pelleted Subterranean Clover*

Pelleted seed has been advocated to stimulate *Rhizobium* growth and thus overcome a postulated antagonism in the rhizosphere. With other evidence suggesting that seed coat inhibition was a factor contributing to poor *Rhizobium* survival, it was desirable to test the pellet response in the presence of a modified soil microbial population.

Soils were treated *in situ* with formaldehyde and sodium methyl dithiocarbamate but these treatments did not benefit nodulation. However, a marked improvement in nodulation was obtained with pelleted seed and seed inoculated with sugar-inoculum slurry. Sugar apparently had a protective rather than stimulative effect on *Rhizobium*.

(*f*) *Other Studies*

(i) *Chemical Composition of Some Grazed Native Pasture Species*

In general the legumes, flatweed, and fine-leaved perennial grasses were high in sulphur, phosphorus, and nitrogen, while the perennial tussock grasses and the rushes and sedges were low in these constituents.

Percentage of sulphur and nitrogen was low when soil moisture was limiting for plant growth, and higher when soil moisture became available for plant growth.

Percentage of sulphur, nitrogen, and phosphorus was high in young actively growing material, declined when flowering commenced, and was low at maturity. Percentage of calcium was not markedly affected by soil moisture or stage of growth.

(ii) *Soil Temperature and Moisture Measurements*

Unusual features in the soil temperature and moisture pattern were recorded during the year. During May and August the mean maximum temperatures at 1 in. depth under bare ground were 6°F above mean values for these months for the preceding 6 years.

Under sown pastures the level of soil moisture during the spring–summer season was not reduced below field capacity until late November, this being about 3–4 weeks later than usual. Under native pastures there were no periods of moisture stress during this season.

13. Pasture Investigations (at Deniliquin, N.S.W.)

(*a*) *Irrigated Pastures*

(1) *Time of Opening Irrigation — Subterranean Clover*.—The grazing trial to assess carrying capacity of irrigated subterranean clover–Wimmera ryegrass pastures laid down in the autumn of 1959 is now in its second year. Opening irrigation in February continues to show the spectacular effects of previous seasons. Ten dry sheep to the acre can be carried for the whole 12 months, as the sheep have ample dry feed. A loss of 25 lb liveweight occurs during the January–March period. Sheep died on the later irrigation treatments at this stocking rate and these

have been discontinued. For each month the first irrigation is delayed the carrying capacity on the whole year basis falls by at least 2 sheep per acre. Increases in wool growth over a 14 week period paid for the extra water used in the early irrigation.

Following demonstration of this trial at a Field Day on October 15, 1959, there has been an increase of early irrigation of subterranean clover pastures from 5000 in 1958 to 15,000 acre feet in 1959 in Berriquin district alone. This represents about an extra 30,000 acres of irrigated pasture being irrigated early.

This trial, with its markedly different rates of pasture growth, has allowed the establishment of relationships between feed available, wool growth, and liveweight gain.

(2) *Role of Subterranean Clover in Summer Nutrition of Sheep*.—The irrigation trial provided an opportunity to study the role of clover seed in the summer diet of sheep. Seed available varied from 900 lb per acre (early irrigation 5 sheep per acre treatment) to 80 lb per acre (late irrigation 10 sheep per acre). Seed consumption in the December to February period approaches 1 lb per head per day. There is an inverse relation between seed consumption and loss of liveweight.

(3) *Insect Damage to Irrigated Pastures*.—Trials to assess the effects of various insects on pasture yields are continuing. *Descantha praemosa* is common and an unidentified weevil was widespread in the 1960 autumn (50 or more adults in the 18 by 18 in. cages). Effects of these infestations on yield of pasture have not been determined.

(4) *Weed Control*.—The promising results obtained by the use of trichloracetic acid (TCA) and "Dalapon" in the control of barley grass (*Hordeum leporinum*) are being investigated in the field.

(*b*) *Irrigation Agronomy*

(1) *Establishment Trials with Dissolved Gypsum*.—Previous trials established the value of dissolved gypsum for establishing pastures on Riverina and Billabong clays. Twelve farm trials have extended this work to a wide range of district soil types. Generally the response to dissolved gypsum increases with percentage exchangeable sodium. A winter program of testing the emergence response on all regional soil types is about to commence. The effect of varying concentrations will be further tested on a selection of these soils in field trials next irrigation season to establish extension recommendations. These trials have been carried out in collaboration with the N.S.W. Department of Agriculture.

(2) *Species Testing*.—The seasonal production of 36 species has been measured since their successful establishment with dissolved gypsum 2 years ago on Riverina clay. Organic matter build-up, an important attribute of plant growth on heavy soils, will be measured under each sward after the final harvest in the near future. The trial area will then be grazed to measure species persistence.

Species production on this soil is found to be considerably lower than on the light soils. To test the effectiveness of dissolved gypsum coupled with deep ripping on these soils, trials of five perennial and five annual species or mixtures have been laid down on two heavy soils and a sandy loam.

The gradual deterioration of plots in the species trial together with unusual weather in some seasons has stressed the difficulty of field testing. From gas exchange measurements on growth of swards of varying leaf area indices at different light intensities and temperatures, it is intended to determine how accurately the potential production of species in a given climate can be assessed by laboratory growth studies. This could be effective for at least screening out unproductive species.

(3) *Wheat Trials.*—Two trials have been laid down with the aim of measuring yields of irrigated wheat. One is a simple comparison of five varieties at two nitrogen levels. The other is a study of the effect of controlling leaf area at different stages of growth on the development and yield of irrigated wheat.

(*c*) *Soil Fertility and Nutrition*

(1) *Nitrogen Fixation of Legumes.*—Poor nitrogen fixation has been found in white and subterranean clovers under glass-house conditions. Response to nitrogen occurs on all of the 10 Riverina soils tested, as well as a red-brown earth from South Australia. Autoclaving, leaching, or the addition of activated carbon to the soil, do not influence the effect. It is small in winter, increases during the spring, and is greatest in summer. With a subtropical legume (*Lotononis bainesii*), however, the reverse occurred, the response being greatest in winter, and least in summer.

In field experiments white clover responded to nitrogen during the summer months; the magnitude of the response may be influenced by cutting regime, and timing of irrigation of the clover stand. In addition to management practices of temperate legumes, the use of subtropical legumes, to increase yields and the amount of nitrogen fixed during the summer months, is being investigated. Species of *Phaseolus, Vigna, Glycine,* etc. are promising.

(2) *Nodulation of Legumes.*—Nodulation problems have been found on Finley loam. In pot culture, barrel medic and *Lotus* species will not nodulate satisfactorily without inoculation, and it occurs more rapidly if calcium carbonate is added to the soil. The yield of barrel medic was increased 13-fold. Clover nodulated with effective native soil rhizobia, but its yield was increased 50% by inoculation, and the addition of calcium carbonate to the soil. These results will not be tested in the field.

On other soils satisfactory nodulation normally occurs from effective native soil rhizobia on white and subterranean clovers and barrel medic. On Riverina clay the rhizobia applied in the seed inoculation could not be recovered from the nodules in both field and pot trials. Introduction of laboratory strains of rhizobia in competition with native soil rhizobia appears difficult.

(3) *Soil Nitrogen Accumulation.*—Long-term field trials testing the influence of the supply of deficient nutrients (nitrogen, phosphorus, and sulphur), and type of pasture (annual and perennial with varying proportions of clover and grass,

and grass with fertilizer nitrogen) on soil nitrogen accumulation under grazing conditions are continuing.

(4) *Other Nutrient Deficiencies.*—Trials to determine whether other nutrients become limiting with the use of superphosphate (to correct phosphorus and sulphur deficiencies) and build-up in soil nitrogen have been carried out on several soils.

In pot culture small responses to iron were found with white clover grown on Finley loam. *Lotononis* responded to B on a similar soil from the Falkiner Memorial Field Station. These responses have not occurred in the field to date.

(5) *Rice and Rice Weeds.*—*Echinichloa crus-galli* is a serious weed of rice. Competition studies between these plants indicate that increasing the supply of nitrogen, phosphorus, and sulphur favours the growth of *Echinochloa* to a greater extent than that of rice, so that rice yields are considerably reduced when the two species occur together. Delaying the application of nitrogen several weeks after the commencement of tillering gave better rice yields than earlier applications, on the soil surface, as *Echinochloa* matures more rapidly than rice.

(*d*) *Soil Fertility — Physical Conditions*

(1) *Short-Term Effect of Gypsum on Sodic Clay Soils.*—The porosity of soil aggregates was substantially increased by speeding up their rate of wetting with electrolyte. Wetting under tension reduced rate of wetting and prevented porosity changes. Rates of wetting controlled by aggregate size and by wetting under tension were found to affect degree of slaking, the slaking in turn controlling the porosity of the aggregate. Slaking may be a further variable which can be manipulated in the field by, for example, cultivation methods, irrigation at levels of moisture, as well as by electrolyte concentration.

(2) *Long-Term Effect of Gypsum on Sodic Soils.*—The assumption, not yet tested, is that gypsum treatment, having established the pasture, will then operate in the long-term through the accumulation of organic matter. Physical and chemical data on Riverina clay suggest that more than one light dressing of gypsum may be needed to achieve a continuing improvement in soil structure. The reason for this is that irrigation water applied after the addition of gypsum will often contain too low a concentration of electrolyte to maintain a stable permeability in the soil. Since only very low concentrations of electrolyte are involved, interest is now being taken in combining a broadcast treatment with the dissolved gypsum treatment. In this way the concentration of calcium in the infiltrating water could be maintained at a point where dispersion would not cause permeability to fall.

(3) *Combining Gypsum and Deep Tillage with the Aim of Deepening the Zone of Root Activity.*—Yields in the first year were generally lower than are expected on irrigated soils in this region. However, treatments which increased the absorption of water by the soil, i.e. ripping and gypsum, gave substantially higher yields. Lack of suitable watering facilities made it impossible to regulate irrigation or to maintain water as a non-limiting factor. Despite this, persistence of the effects of deep tillage and gypsum remain as major items of interest in this trial.

(*e*) *Ecology and Dryland Agronomy*

(1) *Introduced Species.*—In the field between April 1959 and February 1960, a period of average rainfall, poor distribution of rainfall limited yield of forage from natural pasture on a loam soil, to 9.5 cwt per acre. This contrasted strongly with the yield of 20.6 cwt per acre from lucerne (Hunter River variety) which was sown in rows 14 in. apart. However, by using the lucerne variety Hairy Peruvian in 42 in. rows the yield was increased to 31.3 cwt per acre. Even in a most favourable season this yield has never been approached by the natural grassland.

(2) *Endemic Species.*—On clay soils no introduced species were found superior to the natural grassland which produced 9.1 cwt per acre of forage. The best species was lucerne (Hairy Peruvian variety) which produced 6.7 cwt per acre from rows 42 in. apart. Indigenous saltbushes which formerly grew on this type of soil are more promising than exotics.

Techniques of vegetative propagation for several of the indigenous saltbushes, particularly *Atriplex nummularia,* have been investigated with a view to selecting productive strains and constructing synthetic plant communities for the pastoral industry.

(*f*) *Machine for Dissolving Gypsum in Irrigation Water*

The spectacular results of the dissolved gypsum treatment demanded a method for producing large quantities of gypseous water by a continuous process. In cooperation with the Chemical Engineering Section and the Engineering Section a suitable machine has been developed (*see* Chapter 33, Section 4 and Chapter 16, Section 16). Because of the low rate of solution of gypsum in water the system had to provide much agitation, and (to achieve efficient use of gypsum) separation and recycling of undissolved material.

The separators consisted of cylindrical hydraulic cyclones connected in series.

The agitation was provided by a 6 in. centrifugal pump which also supplied the driving head necessary for operation of the cyclones.

The machine was designed to produce 1 cusec of water with a concentration of 10 m-equiv. per litre of $CaSO_4.2H_2O$. Under these conditions the dissolving efficiency was 80%. Upon further testing it was found that the machine could produce 2 cusecs at double the above concentration, thus allowing a maximum irrigation rate of 4 cusecs when dilution is used.

Further work was carried out at Deniliquin on the design and construction of a much simpler machine, the efficiency of which was found equal to that of the prototype.

The effect of particle size and purity on the build-up of recirculating load was determined using a range of samples of known particle size distribution and purity. Machine performance and pump wear were not affected provided some of the recirculating load was bled off after a certain period of operation. The periods varied from 1 hr for the coarser, less pure samples to more than 8 hr for the finer and pure samples.

(*g*) *Genetics — Plant Breeding*

Production of pastures at Deniliquin is low during late autumn and winter, which is often a time of considerable feed shortage. Hunter River Lucerne grows very slowly during this period, and lucerne stands tend to become weed infested during the winter.

(1) *Yields of Varieties.*—A number of lucerne strains from widely differing environments have been tested under grazing, and cutting, irrigation, and dryland conditions. Cut and grazed trails are now in their third and fourth years respectively. Winter active varieties, Indian, African, and Hairy Peruvian, have consistently given double the winter production of that of Hunter River, and 20–30% higher summer production. Production from Canadian creeping rooted is negligible in 4-year-old stands.

(2) *Persistence.*—On 4-year-old grazed stands under irrigation, varieties show large differences in persistence. Plant losses have been greater than Hunter River on badly drained areas in African, Indian, Hairy Peruvian, and all French varieties. Lahontan and a grazing type, Uruguay Clone 10, have shown good persistence. In contrast there has been scarcely any reduction in density on dryland grazed swards.

(3) *Cutting Trials.*—Cutting Hairy Peruvian and Hunter River at immature stages during winter will reduce spring production by 20%, but this effect does not persist with later cuts.

Cutting Hairy Peruvian, at bud stage for the first three cuts, gave 50% higher production than cuts at one-third flowering over a similar period. After this, production from bud stage cuts dropped well below that of stands cut at flowering, and remained below for the rest of the season. With Hunter River, cuts at bud stage gave the same production as flowering stage cuts during spring, after which production for bud stage cuts dropped in the same manner as with Hairy Peruvian.

The lack of vigour of Hunter River under frequent defoliation is reflected in weediness of the stand.

(*h*) *Subterranean Clover*

(1) *Natural Selection Studies.*—Samples of seeds from plots sown in 1955 with a mixture of 13 different strains of subterranean clover have been germinated to estimate the proportions of population contributed by each strain. Mount Barker has become the dominant strain where spring soil moisture is assured.

(2) *Selection Yield Trial.*—An experiment has been sown with 11 hybrid lines, selected in Canberra for early winter growth, together with three standard commercial varieties, and seed taken from spring and optimum watered hybrid populations of the natural selection experiment.

14. Pasture Investigations, Western Australia

(*a*) *Perennial Grasses*

(1) Phalaris tuberosa.—Studies on the growth of *Phalaris* in the Kojonup environment continued. The final experiment in the glass-house on the effect of

soil waterlogging disclosed a marked depressing effect of flooding on phosphate uptake. This is contrary to common belief, and the finding of strong responses to applied phosphate should be of economic interest in extensive areas that suffer from winter waterlogging. Examination of the effect of soil depth on the growth of *Phalaris* has already shown the advantage of deep soil profiles. Further work next summer should provide information on the critical states of hydration of the dormant tiller buds. Study involving both *Phalaris* and veldt grass and 14 different soils at Kojonup has commenced on the plant-soil relationships of perennial grasses. This cooperative study with the Division of Soils should provide an assessment of the soil conditions favourable to the culture of perennial grass.

(2) Hyparrhenia hirta.—Results of grazing trials at Perth clearly indicate the superiority of a *Hyparrhenia* pasture over annual pasture for wether sheep. Whereas 2⅔ sheep per acre is about the maximum carrying capacity for annual pasture at Perth, the figure for *Hyparrhenia* pasture appears to be about 5 sheep per acre.

The 10 strains of *H. hirta* selected for detailed agronomic study in small plots have exhibited marked differences in seasonal production, especially during summer. Promising results are also emerging from a germination trial under field conditions, using a number of strains. Two further studies are being undertaken, one to examine the effect of water-table depth on growth, the other to explore the possibilities of growing *H. hirta* on the more important sand profiles of the Swan Coastal Plain.

(3) *Other Studies*.—In a field experiment at Kojonup using a mowing system to simulate grazing, one strain of *Festuca arundinacea* and two strains of *Lolium perenne* are performing better than two strains of *Phalaris tuberosa*. This is the first indication that there may be perennial grasses superior to *Phalaris* for the Kojonup environment. Another field experiment, using several perennials, has indicated a relationship between depth of rooting and conductivity (as measured by size of metaxylem vessels).

(*b*) *Species and Strain Experiments with Annuals*

(1) *Subterranean Clover*.—The extreme earliness of flowering of the new strain Carnamah has been confirmed. When sown in the autumn to early winter period Carnamah commences flowering from 4 to 2 weeks before Dwalganup. The further studies with this strain — conducted jointly with the University Institute of Agriculture — have shown that the above differences are associated with earlier flower initiation in Carnamah. Another interesting and useful feature of the new strain is its relatively high early growth rate (during the second month of growth). Moderate supplies of seed were built up in 1959, and field trials are now in progress to compare Carnamah with three other strains under sward conditions in low rainfall areas.

Work on the long-term adaptation of clover strains to the Kojonup environment was described last year. These studies are due for completion at the end of 1960. An interesting feature of the data is that strains which have shown superior adaptation in single-strain swards have done so also in admixture. Many strains may coexist in a sward for up to at least 8 years under grazing.

The exploratory trial in which the three commercial strains Dwalganup, Yarloop, and Bacchus Marsh are under continuous stocking (at 2½ sheep/acre) has for the third successive time shown the superiority of Bacchus Marsh over the other strains during summer. Sheep body weights during the dry season were clearly maintained at a higher level. The results are suggestive of maturity grading effects on animal performance. Seed supplies of several non-commercial strains are now being multiplied, with the object of examining nine strains (divided into three maturity groups) under continuous grazing.

Studies on the influence of defoliation on reproductive growth continued using the Dwalganup strain. In single plants, pre-flower initiation defoliation markedly retarded flowering, mainly through an effect on rate of leaf appearance. In the several defoliation treatments imposed, all of them reduced both number of leaves and number of inflorescences, as compared with undefoliated controls. Relative rates of inflorescence production were set fairly early (day 88), and rankings remained unchanged to the late flowering stage (day 130). The picture for sward conditions was quite different. Results confirmed those from last year's field experiment in which two defoliations up to the early flowering stage *increased* inflorescence production, as compared with undefoliated swards. Defoliation has greatly increased the proportion of flowers on laterals as against the main axis. A point of interest was the delay (of *c*. 3 weeks) in median date of commencement of flowering in swards as compared with single plants.

(2) *Brome Grasses*.—A farmlet grazing trial has demonstrated that Californian strains of soft brome grass (*Bromus mollis*) can persist very satisfactorily at Kojonup, with a stocking rate of 3 wether sheep/acre, under a continuous grazing schedule. Indeed, the pastures have maintained an almost pure mixture of soft brome grass and subterranean clover, with virtually no serious ingress of the volunteer ripgut brome grass (*B. rigidus*). Further current work includes the bulking up of two strains for large-scale testing, an examination of a large number of strains for *B. mollis* as single plants, and a preliminary study of relative growth rate during winter.

(*c*) *Plant Nutrition*

(1) *Phosphate*.—Residual effects of both superphosphate and rock phosphate applied to a clover pasture in 1952 are being measured. Pasture yields from plots receiving rock phosphate remain fairly uniform. Over the period 1952–59, total production from the superphosphate was slightly greater than from rock phosphate, at the initial level of application of 8 cwt per acre.

The program is largely concerned with phosphate leaching losses. Following the striking results given last year, the effect of lime and also of rock phosphate on phosphorus loss was examined. Lime at 400 lb per acre had no effect on phosphorus retention and even at 1580 lb per acre the effect was slight. Rock phosphate gave negligible leaching losses, but this advantage is offset (to some extent) by reduced plant availability. Work is continuing (with radioactive ^{32}P)

to define the conditions of phosphate loss. Phosphate sorption studies with virgin soils derived from acid granites have shown a good relation between total phosphorus content and ability to sorb phosphorus. It should be possible to predict soils in which fertilizer phosphorus losses may occur.

(2) *Nitrogen*.—Work on application of nitrogen fertilizers to ungrazed pastures has been continued. In 1959 large responses (80–120%) were again obtained, and these began soon after the season opened. The efficiency of nitrogen use (22 lb dry matter increase per lb applied nitrogen) suggests that fertilizer nitrogen may be profitable. Support for this is available from two plots, one without applied nitrogen, the other with 100 lb nitrogen per acre applied in 1959, both stocked at 5 sheep per acre. Results suggested a marked improvement in the nutritive value of dry feed — mostly cape-weed — during summer.

Part of the nitrogen program is being devoted to a careful chemical study of nitrogen stress in pasture plants. Using Wimmera ryegrass grown under rigidly controlled nitrogen regimes in sand culture, an attempt will be made to establish the most sensitive compound for indicating nitrogen stress.

(3) *Chlorine*.—Glass-house studies have been pursued to examine the effect of chlorine on reproductive development in subterranean clover. As in a previous experiment, chlorine deficiency reduced runner development. However, the Mt. Barker strain was not entirely satisfactory at the high summer temperatures, and the work will be repeated during the winter period of 1960. It now seems possible that lack of persistence of subterranean clover on some inland sandplains may be associated with reproductive failures arising from chlorine deficiency.

(4) *Other Elements*.—Owing to the increasing importance of potassium deficiency, a new series of studies has been initiated on factors affecting potassium uptake by pasture species. The work is being undertaken jointly with the University Institute of Agriculture, and the first experiment will be concerned with root development in several annuals.

Attention will now be given to the nutritional problems of the poor coastal sands near Perth. A pot-culture experiment has already demonstrated acute copper and zinc deficiency in *Hyparrhenia hirta* and subterranean clover on Gavin sand. A field experiment is now in progress on this soil type to explore the possibility of a cobalt deficiency in subterranean clover.

(*d*) *Ecology of Annual-Type Pastures*

The two long-term experiments are proceeding concerned essentially with seasonal changes in botanical composition. In one of these commenced in 1949, a range of phosphate levels has been incorporated, and the main interest centres around changes in clover dominance. There are marked overall differences in percentage clover in the sward with low phosphate ($\frac{1}{4}$ cwt per acre per annum superphosphate) as compared with high phosphate (2 cwt per acre per annum). There was less fluctuation from year to year at the lower level. Moreover, there is no good evidence of "deterioration" in yield, although there has been a perceptible overall decline in percentage clover.

In the second experiment, where three pastures have been under continuous grazing since 1953, no evidence of excessive clover dominance has yet been encountered. This experiment has now been modified to include two stocking rates (2 and 4 sheep per acre), primarily to investigate stocking rate effects on proportion of clover in the pasture.

(*e*) *Pasture Utilization*

(1) *Stocking Rate*.—In view of the known effect of stocking rate on efficiency of pasture utilization, a farmlet trial was commenced in 1958 on annual pasture with 1, 2, 3, 4, and 5 wether sheep per acre. All plots have been continuously grazed throughout. During the two summer periods mean body weights were inversely related to stocking rate. The largest mean difference (> 25 lb per sheep) occurred in mid June 1959, some compensatory gains taking place at the higher stocking rates later in the growing season. At shearing — in early September — wool production ranged from 13.7 lb per head at 1 sheep per acre to 10.9 lb per head at 5 sheep per acre with a progressive decline in the intermediate stocking rates. Wool production per acre, however, ranged from 13.7 lb per acre to 54.7 lb per acre, the relationship again being approximately linear. Additional plots at the 5 sheep per acre rate have been laid down in view of the high wool production figures, and also to examine the influence of applied nitrogen fertilizer (*see* Section (*d*) above).

(2) *Time of Lambing*.—The comprehensive experiment involving three lambing times (autumn, winter, and spring) and three stocking rates 1.5, 3, and 5 ewes per acre) is proceeding satisfactorily. In 1959 differences due to stocking rate were negligible, whilst the numbers of ewes lambed were 75, 52, and 58%, for autumn, winter, and spring lambing, respectively. Thus infertility was marked throughout. As yet it is not known whether "clover infertility disease" was implicated. It is possible that the poor winter lambing was due to high temperatures during mating in the January–February period.

Growth rates of the lambs presented some interesting features. In the autumn lambing group, differences due to stocking rate were clear-cut; in the winter group, differences between the two lower stocking rate treatments were negligible; whilst in the spring group all stocking rate differences were small. However, weight increases in the spring lambing group were retarded from the seventh to twelfth week during seed setting of the annual grass species. Results to date provide no strong argument in favour of spring lambing with Merino sheep.

(3) *Metabolism Studies*.—An experiment in pens with lactating ewes has confirmed results from earlier work (in Canberra) where dry matter intakes of dry ewes were lower than ewes with singles and ewes with twins. The cape-weed dominant pasture used for this study gave low absolute dry matter intakes, although wet matter intakes were in line with those from Canberra. It was found, on further analysis, that dry matter intake declined as percentage dry matter in the cape-weed fell. The species is remarkable for its high percentage water content in winter, and this may impose a "water load" on the ruminant leading to a depression of intake.

In a further pen experiment with wether sheep, dry matter intake of cape-weed pasture was 30% lower than that of a cape-weed–free material, although dry matter digestibility was slightly higher.

(4) *Weaner Investigations*.—A field experiment is in progress with three stocking rates (2, 3.5, and 5 weaner sheep per acre) each with and without a supplement (0.5 lb cut grain per day from December). Weight differences up to mid March of last year were very small, but from then until the "break" of season differences between the controls and supplemented groups increased markedly. Also differences due to stocking rate were small in the supplemented group, but quite large in the unsupplemented controls. These differences in body weight were almost abolished by September, except for the 5 sheep per acre unsupplemented treatment. Weaner mortality in the 1959–60 season was very high (12 out of 20) on this treatment, when compared with the negligible losses in the previous year.

In a lucerne supplementation field trial, extending over 14 weeks, alternate grazing on lucerne pasture either 1 day in 6 or 1 day in 3 (the remainder on dry annual pasture) reduced body weight losses and increased wool growth, when compared with continuous grazing on annual pasture. This perennial species may play a useful role in overcoming the summer nutrition problem in weaner sheep.

(*f*) *Soil Fertility*

(1) *Effects of Phosphate*.—The three field experiments concerned with the relation between phosphate status of the pasture and soil fertility build-up are continuing. Soil nitrogen increases during the last season were generally low, and no further light has been shed on some of the unexpected findings previously reported. Careful lysimeter studies may well assist in an understanding of this complex problem.

(2) *Short-Term Nitrogen Build-up in Clover Pastures*.—This comprehensive experiment, commenced in 1952, has concluded, and results are being prepared for publication. Soil fertility build-up, as measured by a wheat crop, has shown some interesting features. Grain yields increased from 16.6 bushels per acre on the no clover controls to 34.5 bushels per acre after 5 years of clover pasture — an increase of more than twofold. Although the yields increased steadily from 2 to 5 years under clover, the 1-year clover treatment gave yields intermediate between those for 2 and 3 years. Two factors probably contribute to this apparent anomaly; firstly, a dense, almost pure first-year stand of legume, with virtually no nitrogen uptake by non-legumes, and secondly, restricted grazing and consequently small losses of urine nitrogen by volatilization. A few inconsistencies appear in the yield data, however, and these seem to be connected with growth of the clover component in the sward.

A range of fertilizer nitrogen treatments was superimposed on the plots in 1959, but results are not yet available. Symptoms appeared at high levels of applied nitrogen (4–8 cwt/acre calcium ammonium nitrate) which appear to be due to manganese toxicity.

(3) *Effect of Soil Type*.—This field experiment, involving six distinct soil

types, is continuing. During 1959 soil samples collected from the inception of the work in 1954 were used for a glass-house study, in which available soil nitrogen was measured by the wheat plant. In general, the trends observed in the total soil nitrogen figures were correlated with nitrogen uptake by wheat.

(4) *Pasture Management*.—The plots which were originally subjected to three management systems were sown to wheat for the third time. It is apparent from the cereal yields, which are in line with the soil nitrogen data, that the sheep has played an unimportant role in soil fertility build-up. Moreover, data point to the significance of the root fraction of the clover plant in building up soil fertility.

(5) *Urine-Nitrogen Losses*.—Recent studies have confirmed the large losses of nitrogen which can occur from sheep urine applied to pastured soil. On a sandy soil from 74 to 88% of the nitrogen was lost, whereas on a heavier-textured soil the loss was reduced to *c*. 50%. In the latter case a large proportion of the residual nitrogen accumulated as inorganic nitrogen. Urine application was followed by pronounced changes in soil pH; after 24 hr the pH increased from 5.9 to a maximum of 9.7 in sandy soil and to 8.6 in heavy soil. Values fell slowly with loss of nitrate nitrogen from the soil. Further studies are being undertaken in small lysimeters, in which leaching losses will be examined as well as losses by volatilization.

15. Fruit Investigations (at Hobart, and at Applethorpe, Qld)

(i) *Physiology of Apples in Relation to Storage Disorders*

Professor J. Bonner had suggested that it might be possible to correct some of the "climatic lesions" of apples grown in the maritime climate of Tasmania by the addition of chemical supplements. Adenine, guanine, and vitamin B_1, were proposed, and these have now been tested for three successive seasons. There have been no significant effects on the cell number or physiology of the fruit except a slight reduction in the incidence of Jonathan spot. Better results have been obtained with casein hydrolysate which give hope that supplements may be found which could improve fruit quality.

Attempts to increase cell number per fruit continued by using kinetin, alone and in combination with IAA, DPU, and casein hydrolysate. These were compared with the effects of reduced competition in the inflorescence produced by blossom thinning by hand, or by DNOC sprays, or by reducing embryo competition by abortifacients ANA and 2,4-D.

Small but significant effects can be induced by these treatments but in the case of ANA and 2,4-D they are not sustained. They are all of a much lower order than occur naturally either between seasons or between cropping level within a season as the result of growth and crop conditions in the previous season. The metabolites necessary to sustain cell division in the fruit may accumulate in the body of the tree and are conditioned by events in the previous year. Stimuli provided by fertilization or other means at the time of cell division have minor effect. Investigations on apple kinins now in progress at Canberra may produce cell division stimulants of greater potency than those used.

Calcium reserves may play a part. Treatment with calcium salts has increased cell number and magnesium has reduced it.

A relation between mean seed number per fruit and the incidence of Jonathan spot has now been established. Conditions resulting in increased numbers of seed may not be advantageous to fruit storage. The 1956 season, which was an outstanding year in cropping level and keeping quality, was one of abnormally low seed number.

(ii) *Apple Scald*

Diphenylamine at high spray concentration of up to 4000 p.p.m., with picking within 24 hr, is a satisfactory control.

(iii) *Mineral Balance in Relation to Disorder*

(1) *Bitter Pit*.—The 1959 results have confirmed that bitter pit in the variety Cleopatra is related to calcium status and can be reduced in incidence up to 75% by sprays of calcium salts and greatly increased by sprays of magnesium salts. Potassium and boron have had no effect.

(2) *Cropping Level*.—Very wide fluctuations of calcium content in fruit between seasons have been demonstrated. The level in 1959 was only one-third that in 1958. Other mineral elements showed very much smaller variations. This variation is due to the effect of previous crops, but it may also be affected by water stress induced by high evaporation conditions.

(iv) *Internal Atmospheres of Apples*

These studies were continued using two size groups of two cropping levels of the varieties Cox and Jonathan. The principal results were:

At harvest, internal CO_2 is at a much higher level in Cox than in Jonathan but within each variety mean CO_2 level was not related to fruit size within a tree or to crop differences between trees. Respiration rate was higher in Jonathan than in Cox, the internal CO_2 level of a variety being thus not dependent on respiration rate but on skin permeability.

For the first time recorded, respiration rate was higher in light than heavy crop fruit and in large size Jonathans than in small but there was no significant difference in respiratory quotient. Respiration per unit protein was higher in light than in heavy crop fruit.

Individual fruits showed a striking intercorrelation between respiration rate, protein nitrogen content, and internal CO_2 level, the relationship between respiration rate and CO_2 level remaining significant even when protein nitrogen content was held constant by partial correlation.

For fruits of different sizes from the same tree the regression lines of respiration rate and protein nitrogen were parallel and not separated significantly, but between heavy and light crop fruit the regression lines were significantly separated.

(v) *Fruit Maturity*

Borax sprays hasten maturity and produce more even ripening of Jonathan apples. Total harvest of treated trees was attained in two pickings while three were required for untreated trees. Fruit matured 7 days earlier when trees were sprayed. There was no difference between treatments of 5 or 10 lb of borax per 100 gal.

(vi) *Cell Number in Apples*

Cell number and weight of fruits, 10 weeks after full bloom, are drastically reduced by zinc deficiency. Fruit from zinc deficient branches had 10.4×10^6 cells and weighed 18.2 g while fruit from healthy branches of the same tree had 23.1×10^6 cells and weighed 50.1 g.

(vii) *Rootstock Trials*

In a rootstock trial at Applethorpe over the past 20 years Granny Smith yielded best from medium-sized trees, Jonathan from vigorously growing large trees, and Delicious from small trees. Parallel experiments with Williams variety of pears established 7 years ago have not yet given clear indications of fruiting habits.

Storage quality was not affected by fertilizer treatment or rootstock used.

16. Tobacco Investigations (at Mareeba, Qld)

(i) *Agronomy and Physiology*

(1) *Nitrogen Studies.*—Nitrate content of the soil falls markedly at the time of first irrigation, and is associated with a decrease in soil carbon. Isotopic nitrogen (^{15}N) is now being used to follow transformations of nitrogen in the soil and its uptake by the plant.

A nitrogen balance sheet has demonstrated that normal fertilizer additions supply less than one-fifth of the plant's nitrogen needs. High nitrogen applications in the field (up to 65 lb nitrogen per acre) failed to cause clear response in yield of cured leaf. The value per plot was, indeed, greatest at the lowest nitrogen level (5 lb nitrogen per acre).

Plant analysis showed that, between the time of topping and leaf maturation, there was little or no net movement of nitrogen into the leaves; their growth consequently led to a considerable decline in nitrogen content on a percentage basis.

The absolute nitrogen content of the other aerial organs, however, increased during this period.

(2) *Effects of Halogens.*—Glass-house experiments and three field trials on different soil types were conducted to study uptake of chlorine and bromine. Applications of the nematocide ethylene dibromide were varied, and were combined with different fertilizer and watering treatments. It has been found that considerable amounts of bromine can be taken up by the plant following applications of ethylene dibromide, and that the halogen content of leaves at harvest time can be markedly modified by fertilizer treatments and by the irrigation regime.

(3) *Irrigation and Water Relations.*—Experiments continued on the effect of beginning irrigation at different intervals after planting. During the 1959–60 season, when an epiphytotic of blue mould (*Peronospora tabacina*) developed early, delaying irrigation until the fifth week was advantageous.

An investigation is in progress to compare the value of different physiological measurements as indices of water stress within the plant, and hence of the need for irrigation.

Field trials during 1959–60 compared the value of furrow and spray irrigation as techniques for field experimentation.

(4) *General*.—Experiments were done to compare the quality of leaf from plants established in the field at different dates. Investigations began on the course of development of leaf primordia at the stem apex, and on their subsequent expansion.

(ii) *Plant Breeding*

Comparisons among existing commercial varieties have been continued in the program of breeding new varieties capable of high yields and good quality under north Queensland conditions.

Studies on the mode of inheritance of resistance to blue mould (*Peronospora tabacina*) have shown that resistance thought to be derived from several different sources was in fact genetically identical. Breeding for blue-mould resistance has continued, and a large number of progenies carrying this character have been grown, some of which appear quite promising in the quality of cured leaf obtained.

(iii) *Biochemistry*

Changes in the starch content of growing leaves have been estimated in weekly samples by extraction of the starch with perchloric acid and estimation of the starch after precipitation as the iodine complex followed by acid hydrolysis to glucose. Starch content shows an increase near commercial ripeness and from measurements on large-scale samples its amylose content increases at the same time. The proportion of the whole starch converted to maltose by β-amylase was not found to vary during an 8-week growing period of the leaf through maturation and senescence. Starch content was found to be lower than previously reported values.

17. Mineral Nutrition Investigations (at University of Melbourne)

(i) *Silicon Investigations*

The work on silicon has been carried out in collaboration with officers of the Mineragraphic Investigations, C.S.I.R.O. (*see* Chapter 35), the School of Agriculture, University of Melbourne, and the Division of Building Research, C.S.I.R.O.

Silicon has not been found essential for plants and animals. It is, however, widely distributed in plant and animal tissues where it is present as silicon dioxide (silica) in various forms or as silicic acids with varying proportions of Si : O : H. The present work is aimed at understanding the chemical and physical forms and reactions of silica in the cycle: soil — plant — animal.

(1) *Silica in Plants*.—Plants absorb silica in soluble form from soils and a substantial proportion of the total silica absorbed is precipitated as insoluble particles of microscopic size within the plant tissues. These particles are opaline

($SiO_2 . nH_2O$) and are known as opal phytoliths. The proportion of opal phytoliths to total silica varies with the stage of growth of the plant and approaches 100% at maturity. The amount of opal phytoliths also varies from one plant species to another. For example, Wimmera ryegrass (*Lolium rigidum*) sampled at early flowering contains 4.0% opal phytoliths, while lucerne (*Medicago sativa*) contains 0.2%.

Work on silica in plants emphasizes that the total amount of silica ingested by herbivorous animals may be substantial. The following projects have been undertaken to assess effects on sheep of silica which is ingested in both insoluble and soluble forms in plant food.

(2) *Wear in Sheep's Teeth.*—The Knoop hardness of opal phytoliths has been found to be 590–610. This is harder than the tissues of sheep's teeth which range in Knoop hardness from 33 in the pulp chamber to 382 in the enamel. Opal phytoliths are abrasive, and it is suggested that they are agents of wear of teeth. Amount of wear will depend on the intake of opal phytoliths which in turn depends on the plant food. Intake and wear will be least when the diet consists of herbaceous species and highest when the diet consists of gramineous species.

(3) *Opal Phytoliths and Mineral Particles in the Rumen.*—Plant foods and rumen contents of sheep on different diets have been examined both before and after removing organic matter with perchloric acid. With organic matter removed, insoluble residues were found to consist largely of opal phytoliths. Accompanying the opal phytoliths were small proportions of adventitious mineral particles. These are mechanically incorporated with the food and ingested by the sheep; they were more common in the ventral than in the dorsal regions of the rumen.

The quantity of particulate matter (opal phytoliths plus adventitious minerals) in the rumen varies with the plant food. On a diet of Wimmera ryegrass the rumen contained approximately 20 g, on a diet of oats it contained 10 g, and on a diet of lucerne there was less than 1 g. The proportion of opal phytoliths varies with the plant food and ranged from 8.8% of the total particulate matter with lucerne to 95% with Wimmera ryegrass.

The stratum corneum of the rumen was thinner in lambs fed on Wimmera ryegrass than in lambs fed on lucerne. The depth of this layer may be determined by the amount of wear which depends, for the most part, on the content of opal phytoliths in the plant food.

(4) *Silica Urolithiasis.*—Sheep ingest soluble silica (silicic acid) in their plant food. While it is mostly absorbed from the alimentary tract and excreted in urine, a small proportion is excreted in faeces. Under some conditions silica may be precipitated in the kidneys, ureter, bladder, or uretha to form uroliths (calculi). Chemical and physical studies have shown that siliceous uroliths are opaline and concretionary. They contain magnesium, organic matter, and opal phytoliths. All these accessory constituents may play a role in precipitation of siliceous uroliths.

(ii) *Molybdenum Investigations*

(1) *Examination of Molybdenum-Deficient Soils.*—A wide range of Victorian soils in which molybdenum deficiency is known to occur has been examined by

chemical and mineralogical methods. Pot experiments on these soils have been conducted to determine availability to plants of the native molybdenum.

(2) *Interactions of Molybdenum, Manganese, and Iron in Nutrition of Plants*.—In culture solutions it has been found that the uptake of molybdenum by tomatoes is decreased by raising the level of iron in the solution. On the other hand, if tomatoes are grown at low iron levels they can be thrown into acute iron deficiency by raising the level of molybdenum. Both these effects fit in with the known chemical affinity of iron and molybdenum and could be due to the precipitation of very insoluble ferric molybdates within the plant root.

4

Division of Tropical Pastures

1. General

The Division of Tropical Pastures is a group based on Brisbane which studies the pastoral problems of northern Australia. This group was formerly part of the Division of Plant Industry, and has recently been given the status of an independent Division. Pasture research for northern Australia has undergone considerable development recently, and there has been a growing awareness of the enormous undeveloped pastoral potential of this region.

The pastoral industry of northern Australia is almost wholly based on native or induced pastures. These have a short summer growing season, when the pastures make good growth and have quite good feeding value. There is a longer autumn to early summer period when the pastures make little active growth and feeding value declines. Thus, by the late winter, animals on these pastures lose weight. The pastures have no significant legume component and the protein content of native grass species, which is only moderate in periods of active growth, falls to deficiency levels by late winter.

The Division of Tropical Pastures is engaged in a comprehensive program which aims to supplement and replace the native pastures with more productive sown pastures, and fodder and protein grain crops. Close collaboration is maintained with the regional research group of the Division of Soils which provides valuable information on the distribution and characteristics of the soils of pastoral regions (*see* Chapter 2).

The Division's headquarters are the Cunningham Laboratory, St. Lucia, Brisbane. Facilities for field work are available at the Cooper Laboratory, Lawes, and the Pasture Research Station, Samford; the main regional experiment centres are at Beerwah, Rodds Bay, Brian Pastures, "Nunbank" (near Taroom), and "Tarewinnabar" (near Goondiwindi). This chapter describes the work of the Division of Tropical Pastures.

The Division of Tropical Pastures works in close association with the Division of Plant Industry (*see* Chapter 3), which for many years has been concerned with the establishment, utilization, and maintenance of improved pastures throughout the diverse climatic regions of Australia.

The Division of Land Research and Regional Survey is investigating problems of pastoral development in the dry monsoon zones of northern Australia and in the arid interior (*see* Chapter 13).

The three Divisions of the Animal Research Laboratories are all concerned in various ways with improvement of cattle nutrition in northern areas. Specific problems in this field which are under investigation include resistance to internal and external parasites, digestibility of pasture components, and development of strains of cattle suitable for tropical environments. Research on these projects is recorded in Chapters 7, 8, and 9.

The Division of Entomology is studying insect pests which adversely affect animal production in the north (*see* Chapter 11).

The Wildlife Survey Section is seeking measures for controlling populations of those wild animals which compete or interfere with the grazing industries in northern regions of the continent (*see* Chapter 12).

The Cunningham Laboratory was officially opened on November 30, 1959, by the Prime Minister, the Right Honourable R. G. Menzies, C.H., Q.C., M.P. In addition to staff of the Division of Tropical Pastures, the Cunningham Laboratory houses research groups from the Divisions of Soils, Plant Industry, Entomology, and Mathematical Statistics.

The Chief of the Division, Dr. J. Griffiths Davies, left on a visit to scientific centres in South America, Europe, and the United States. While overseas Dr. Davies will again lead the Australian Delegation to the VIIIth International Grassland Congress at Reading, England.

During the year a symposium on "Nitrogen in Tropical Agriculture" was held in the Division, and this was successful in bringing together for discussion a group of scientists actively interested in this subject.

The Division expresses its gratitude to the Queensland Departments of Agriculture and Stock, Education, and Forestry, to the United Graziers' Association, and to several private graziers for assistance in the research program.

2. Agrostology

(i) *Spear Grass Region*

(1) *Rodds Bay Experiment Centre*.—The continued superiority of sown pasture over native pasture was demonstrated by the following average liveweight changes in grazing experiments with steers during the 1959–60 season:

Period June 2, 1959 to November 4, 1959 (Winter and Spring):

Native pasture	Loss 134 lb/head
Native pasture + Townsville lucerne	Loss 57 lb/head
Native pasture + *Phaseolus lathyroides* + Centro.	Gain 51 lb/head.

Period June 2, 1959 to April 28, 1960:

Native pasture	Gain 138 lb/head
Native pasture + Townsville lucerne	Gain 308 lb/head
Native pasture + *Phaseolus lathyroides* + Centro.	Gain 337 lb/head.

Because of the higher stocking rates possible on sown pastures, the liveweight gains *per acre* show an even greater advantage for sown pastures. Liveweight gains in the 1959–60 season were: native pasture 15 lb per acre; native pasture with Townsville lucerne 110 lb per acre; sown pasture 153 lb per acre.

The oversowing of *Stylosanthes sundaica* (Townsville lucerne) into native pastures has been tested over 6 years. With regular applications of phosphorus and potash, the legume has maintained itself and production of beef has steadily increased over this period. This pasture can now be safely recommended.

The provision of adequate nitrogen remains the major problem with sown pastures based on introduced grasses. *Centrosema pubescens* (Centro.) has remained in pastures for 3 years, but is not supplying enough nitrogen to enable the grasses to achieve their yield potential. Other legumes are being evaluated in this environment.

A comparative study of twelve Rhodes grass strains has revealed wide differences in the palatability of both young summer growth and mature stand-over material.

(2) *Brian Pastures.*—Lack of seed has hampered further work with introduced species of *Stylosanthes*. Those established have continued to grow well on the granitic soil and a study has commenced of their phosphate requirements.

(ii) *Wallum Country*

Productive pastures have now been maintained at Beerwah for periods of up to 7 years and have been under continuous grazing for up to 3½ years. Species which have proved adapted to the region are the grasses *Paspalum dilatatum*, *P. commersonii*, *P. plicatulum*, *P. notatum*, and *Digitaria decumbens*, and the legumes *Phaseolus lathyroides*, *P. atropurpureus*, *Desmodium uncinatum*, *D. intortum*, *D. sandwicense*, *Lotononis bainesii*, lucerne, and white clover. Studies of the responses of some of the more productive grasses to fertilizer nitrogen have commenced with an experiment on *Digitaria decumbens* under a range of nitrogen and cutting treatments.

Basic data on the economics of pasture establishment, maintenance, and stocking in this region are now required. Attention is therefore being directed to soil fertility maintenance, the seasonal production of the more promising species, and animal production. While costs of establishment can be reduced by restricing soil preparation to removal of the natural plant cover, little reduction in fertilizer dressings appears possible. Stocking rates on grazing trials have been increased to one cattle beast to 1½ acres and 7½ sheep per acre; the average liveweight gain in cattle in 1959 was 200 lb per acre.

(iii) *Brigalow Region*

(1) *Regional Field Experiments.*—The pasture experiments in progress near Collinsville, Taroom, and Goondiwindi and at the Cooper Laboratory, Lawes, give a coverage of the climate, soil, and vegetation types representative of the full latitudinal extent of the brigalow country in Queensland.

Sorghum almum and buffel grass are thriving at all centres, while Rhodes grass and *Panicum* spp. are outstanding at Taroom and Goondiwindi respectively. Although lucerne is the best pasture legume at the southern experiment centres, *Glycine javanica* and *Phaseolus atropurpureus* have also grown well. The marked interstrain variation in *Glycine javanica* is being studied to develop strains better adapted to the environment of the brigalow region.

(2) *Grazing Management.—A Sorghum almum* grazing experiment at the Cooper Laboratory was first stocked in April 1959 three months after establishment. The experiment includes three stocking rates and the average annual liveweight gains were: beast to 1½ acres, 370 lb; beast to 1 acre, 335 lb; beast to ½ acre, 220 lb. Loss of weight in the winter occurred only at the heaviest stocking rate. The summer grazing legumes *Glycine javanica* and *Phaseolus atropurpureus* increased in density in the second season but lucerne establishment was only fair. So far there is no evidence that differences in the legume component, or the use of nitrogen fertilizer, have influenced liveweight gains. An experiment has commenced to determine the response of *S. almum* to various rates of applied nitrogen, and the effect of the grazing animal on this response.

(iv) *Plant Competition*

Competition between *Phaseolus lathyroides* and *Paspalum commersonii* for water, nutrients, and light has been recorded, but no evidence of growth suppression by phytotoxins was found. *P. lathyroides* did not survive repeated low cutting because the buds of cotyledon axils in shaded plants did not produce vigorous regrowth. *P. lathyroides* is thus a weak competitor for light, and its failure to persist in pasture mixtures may be due to this characteristic.

(v) *Species Assessment*

An experiment comparing the yield and seasonal growth pattern of 24 species and strains of *Paspalum* has shown that several have a higher yield potential than *P. dilatatum*. An experiment to extend the comparison under grazing has been established, and a collection of *Trifolium* spp. from the high mountains of equatorial Africa is being studied in the field.

3. Supporting Research Groups

(i) *Ecology*

(1) *Autecology of Brigalow.*—Because of the serious practical problem of sucker regrowth from roots following the clearing of brigalow "scrub", a study of the autecology of brigalow has been commenced. It has been found that brigalow roots penetrate to great depths, and that any root near the surface can produce numerous suckers. Heavy regrowth from root suckers can follow mechanical clearing or burning, but trees with a high gum content at the time of disturbance do not sucker. The degree of suckering is apparently influenced by soil type, and heavy mortality of suckers through insect damage has been observed.

Although brigalow is classified as a single species, it appears to contain a number of ecotypes with different reactions to the environment. This could account for the difficulties encountered in attempting to eradicate the species with a single application of one treatment.

(2) *Spear Grass Region.*—An ecological study of 1000 square miles of country between Goomeri and the coastal lowlands has been completed. The soils are predominantly red-earth residuals, solodics, podzolics, and lithosols carrying a mixture of grassy forest, dry sclerophyll forest, layered forest, woodlands, and vine forest. An important connexion has been noted between lithology and the distribution of eucalypt species. Andesites seldom carry more than five species, whereas granites usually support from 8 to 12. The non-calcareous sedimentary formations carry up to 16 different eucalypts, and seven species occur on limestones, five of which are rarely found on other sediments. Each of the sedimentary formations has its own characteristic frequency distribution of common species. It may prove possible to use the number and frequency distribution of eucalypt species as an indicator of the development potential of soils derived from different parent materials.

(ii) *Legume Bacteriology*

A number of cultures derived from Australian native legumes was added to the *Rhizobium* collection. During the year, 504 cultures representing 27 genera were supplied for use in field and glass-house experiments. The nitrogen-fixing ability of numerous *Rhizobium* strains on several African species of *Trifolium* and on several species of *Stylosanthes* was examined. Although one variety of *Stylosanthes gracilis* and *Stylosanthes bojeri* appeared to have identical reactions, two varieties of *S. gracilis* did not nodulate effectively. It appears that some *Stylosanthes* introductions have highly specific *Rhizobium* requirements.

Following the investigation on the calcium and magnesium nutrition of *Rhizobium*, a new system involving the use of two distinct culture media to maintain stock cultures has been devised. Non-acid producers are kept on yeast-extract mannitol agar with calcium omitted but magnesium added; acid producing strains are kept on agar with calcium carbonate added.

Examination of *Trifolium* species native to the mountains of equatorial Africa has shown that while one group (*T. semipilosum*, *T. cheranganiense*, *T. masaiense*, and *T. burchellianum*) are highly strain specific, a second group (*T. usambarense*, *T. tembense*, *T. rueppellianum*, and *T. steudneri*) are less exacting, and will nodulate with a number of strains derived from members of the group.

In a study of the interrelationship of the clover and pea cross-inoculation groups, field peas and vetches were inoculated with strains of *Rhizobium* derived from European clovers, and African clovers. No effective nodulation occurred on either pea or vetch, but there was some ineffective nodulation similar to that produced by ineffective strains from within the pea cross-inoculation group.

(iii) *Pasture Evaluation and Animal Nutrition*

The research officer conducting this work is absent on a Divisional Studentship in England.

(iv) *Plant Breeding and Genetics*

(1) Indigofera spicata.—A feeding test with mice using liver damage as the criterion of toxicity has been developed to test hybrid progenies in this toxic but agronomically promising species. A range of toxicity was found in an F_2 population from crosses between strains from Africa and Ceylon. Toxicity, seeding ability, and morphological characters are being studied in the F_3 generation.

(2) Leucaena glauca.—Desirable agronomic characters are being selected in an F_2 population derived from a series of interstrain crosses, and the mode of inheritance of important characters is being studied. More precise analytical techniques have shown a lack of variation in mimosine content in this species. As mimosine is not toxic to ruminants under normal grazing conditions, breeding for low mimosine content has been discontinued.

(3) Phaseolus atropurpureus.—Superior hybrids giving twice the dry matter and protein yields of the higher yielding parent under grazing have been selected from a cross of two Mexican strains. The F_4 generation of these hybrids (0.3% of the original F_2 population) have a strong stoloniferous development, relatively small leaves, and the ability to maintain a high density under grazing.

(4) *Pulse Crops*.—Ten promising strains selected from a large number of soybean introductions from temperate and tropical regions have been tested in a semi-commercial trial at the Cooper Laboratory; all yielded in excess of 1100 lb per acre, and five in excess of 1500 lb per acre. The relation between major plant characters and yielding ability has been studied, and a crossing program commenced using parental strains possessing characters highly correlated with yielding ability.

(5) Sorghum almum.—Following an examination of the yield and growth characteristics of a large collection of strains of this species, a polycross nursery containing 30 selections was established. Yield, degree of self-incompatability, response to nitrogen, seed colour, stem sweetness, type of root system, perenniality, and male sterility are being studied in the progeny. Some artificial tetraploids are being produced from 20 chromosome species of *Sorghum* (*S. almum* is a 40-chromosome type) in an attempt to improve some of these characters in *S. almum* by interspecific crosses.

(6) *Lucerne*.—A low recovery of creeping rooted hybrids has been obtained in F_1, F_2, and F_3 families derived from crosses between Canadian creeping rooted lucerne and types adapted to lower latitudes in Australia, South America, and India. The majority of these hybrids are winter-dormant. Selected winter-active creeping rooted plants with a high general combining ability for creeping rootedness are being intercrossed to develop varieties adapted to summer rainfall environments in Australia.

(v) *Plant Chemistry*

(1) Leucaena glauca.—Further investigations of the chemistry and physiological action of mimosine from *Leucaena glauca* have shown that it is not toxic to ruminants, under normal grazing conditions. Experiments in which mimosine was

fed to sheep were carried out in collaboration with the Division of Animal Physiology. Mimosine introduced directly into the bloodstream or abomasum caused follicle degeneration, but 10 times the dose was necessary before mimosine introduced into the rumen produced similar effects. Thus while mimosine is the agent causing loss of fleece in sheep, it is rapidly destroyed in the rumen under normal conditions, and therefore acts as a depilatory only when *L. glauca* forms the major part of the animal's diet. As the chemical methods for the estimation of mimosine were not sufficiently sensitive or specific for studies of plant and animal metabolism, new methods have been devised, by using a combination of ion exchange and paper chromatography techniques.

(2) Indigofera spicata.—In the continued investigation of aliphatic nitro compounds in four *Indigofera* species, it was found that the seedlings of all species contained quite high levels of 3-nitropropionic acid, although earlier work with two of the species had shown only low levels in mature plants. Attempts to study the biosynthesis of these compounds using ^{14}C labelled compounds have shown that none of those used was a direct precursor of this nitro acid.

Work on the isolation of the liver toxin in *I. spicata* has been concentrated on methods of extraction which avoid the high losses associated with previous methods. Some success has been achieved, but large quantities of material must be processed to obtain sufficient quantity of the toxic fraction for further investigation.

(vi) *Plant Nutrition*

The main emphasis in plant nutrition is on ion uptake studies and the mineral nutrition of pasture species. New field experiments on the calcium, molybdenum, and phosphate status of a granite soil at D'Aguilar have been commenced. Fertility studies of selected soils are being conducted by the Division of Soils in the joint Soils–Tropical Pastures soil fertility section.

(1) *Characterization of Species*.—Solution culture experiments on the effects of high levels of manganese on pasture plants have shown that levels causing severe foliar symptoms in lucerne and *Phaseolus lathyroides* had much less effect on *Centrosema pubescens* and *Desmodium uncinatum*. Grass species were relatively unaffected.

A water culture experiment has indicated that the minimum phosphate level at which pasture legumes can make maximum growth is approximately 0.5 p.p.m. in solution. The species tested did not differ in their minimum phosphate requirement.

(2) *Ion Uptake Studies*.—The first results of work on phosphate uptake using excised root techniques and ^{31}P labelled with ^{32}P have shown that *Desmodium uncinatum* takes up more phosphate at low concentrations than *Phaseolus lathyroides*, which in turn is more effective than lucerne. At relatively high concentrations the order is the same but the differences are less pronounced. At low phosphate concentrations the increase of pH from 4 to 6 had little effect on

phosphate uptake by lucerne, but uptake by *P. lathyroides* was increased threefold and by *D. uncinatum* reduced to one-third. Cultural techniques have been devised for comparison of the phosphate uptake of whole plants and excised roots.

(vii) *Soil Fertility*

(1) *Nitrogen Fertilizers.*—Rhodes grass has given annual yield responses of up to 20,000 lb dry matter per acre to heavy nitrogen applications (800 lb nitrogen per acre) at Samford. Control plots, where all other deficiencies except nitrogen were eliminated, yielded a maximum of 4000 lb dry matter per acre per annum. *Paspalum* spp. were less productive than Rhodes grass in this experiment.

At low rates of application (25–50 lb nitrogen per acre) very little applied nitrogen was found in harvested samples but at higher rates (200–400 lb nitrogen per acre) up to 50% of applied nitrogen was recovered in Rhodes grass tops. Higher nitrogen rates (200–800 lb nitrogen per acre) enabled Rhodes grass to invade both native pastures (blue couch) and sown pastures (*Paspalum* spp.).

The relationship between soil moisture availability and nitrogen nutrition has been examined on Rhodes grass pasture. The occurrence of stunted, pale yellow, partly desiccated plants in late summer was directly attributable to acute nitrogen deficiency, and not to drought or low temperature effects.

(2) *^{15}N Studies.*—A program has been commenced on the dynamics of nitrogen transformations in grassland soils, concentrating on pathways by which fertilizer is incorporated into soils, plants, and microorganisms, and lost from the soil-plant system. Rhodes grass fertilized with ^{15}N-labelled ammonium nitrate has been grown, and the fate of the labelled fertilizer will be traced when material harvested from this experiment is analysed in the mass spectrometer.

(3) *Legume Nitrogen.*—Selected pasture legumes (white clover, lucerne, *Desmodium uncinatum,* and *Indigofera spicata*) differ in the amount of nitrogen which they make available to a companion grass under a cutting regime. The factors controlling this transfer are being further investigated.

(viii) *Plant Physiology*

Many plants are seriously affected by low temperatures which are just above the freezing point (chilling injury). In the program on low temperature damage to tropical pasture plants attention has therefore been concentrated on the range 32.5–39°F. Young plants of *Centrosema pubescens* were subjected to temperatures in this range for periods of from 2 to 24 hr, but no detectable leaf injury or change in the free amino acid content was observed in any treatment. Closer experimental control of the environment will be necessary to develop this work.

A senior plant physiologist has been appointed to undertake a program of research on the physiological factors controlling the growth and reproduction of tropical pasture plants.

5

Irrigation Research Stations

1. General

The Commonwealth Research Station (Murray Irrigation Areas), Merbein, Vic., and the Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, N.S.W., are the Organization's two main centres for research on irrigation and drainage.

As the driest of the continents, Australia has a special interest in the efficient use of water for all purposes, especially irrigation. Large-scale irrigation raises problems of drainage, and investigations on both subjects are closely linked. This chapter describes the work of the Irrigation Research Stations at Merbein and Griffith.

Much of the work of the Division of Soils has a direct bearing on irrigation (*see* Chapter 2). Irrigated pastures are studied by the Division of Plant Industry, especially at Deniliquin, N.S.W. (*see* Chapter 3, Section 13). The Division of Land Research and Regional Survey undertakes research on irrigation in tropical areas (*see* Chapter 13). Conservation of water supplies for irrigation and other purposes by restriction of evaporation is investigated by the Division of Physical Chemistry (*see* Chapter 30, Section 2).

The Irrigation Research Stations at Merbein and Griffith continue to play their part in the integration of community activity in the approach to irrigation problems, at both regional and national levels. This community of interest is important in irrigation farming, where success depends on the close cooperation of farmers, processors, local organizations, and Government authorities.

The Senior Officer-in-Charge represents C.S.I.R.O. on the Australian National Committee of the International Commission on Irrigation and Drainage. The Officer-in-Charge, Griffith, is one of the Organization's representatives on the Blowering Dam Investigations Committee. This Committee has under review new irrigation areas in the Murrumbidgee region.

The Departments of Agriculture in New South Wales, Victoria, and South Australia, the Water Conservation and Irrigation Commission of New South Wales, and the State Rivers and Water Supply Commission of Victoria have all continued to cooperate in the work of the Irrigation Research Stations.

Movements of underground water and related problems of soil salinity and land reclamation continued as basic research themes at both Stations.

Contributions to the funds of Merbein Station have continued from the Commonwealth Dried Fruits Control Board, the Mildura Packers' Association, Co-operated Dried Fruit Sales Pty. Ltd., and the Nyah-Woorinen Enquiry Committee. The Water Conservation and Irrigation Commission of New South Wales has arranged to increase its contribution to the funds of the Griffith Station, for a joint research project to evaluate the salt hazard to ricelands in the Murrumbidgee Irrigation Areas.

2. Merbein

(i) *Irrigation and Drainage*

A sultana irrigation trial at the Research Station compared watering early-in-the-roster with that late-in-the-roster. There were no differences in yields between treatments. This season, the early-in-the-roster treatment was not associated with a "run-through", which is virtually an extra pre-harvest irrigation, and which has been a factor in earlier years of this trial.

In an investigation aimed at possible methods of frost prevention, the effects were tested of four different treatments on air temperatures in the vineyard — dry cultivation, soil compaction, light irrigation, and heavy irrigation. No significant trends were found in the air temperatures for the different plots. There were, however, marked differences between plots in the heat flow towards the soil surface. This work was done in cooperation with the State Rivers and Water Supply Commission, Victoria, and the Division of Meteorological Physics.

A large proportion of the steady-state drain flow in a medium-textured Mallee soil was found to be contributed by the irrigation furrow over the drain. Infiltration from this furrow was greater than that from between-drain furrows.

As part of the program to determine the properties of the aquifer underlying the irrigation districts around Mildura, further observation wells have been sunk on the Research Station properties at Merbein and Coomealla. Pumping trials are in progress.

By using an electrical analogue, the variation, between drains, of water-table height in stratified soils overlying an aquifer was examined. Results showed that the height of the water-table is considerably affected by the permeability of the soil layers above the aquifer.

Conditions within a soil section having four horizontal layers were reproduced on the analogue. The depth of the artesian aquifer, and the permeability of the soil layer immediately above the aquifer were found to have a dominant effect on the water-table height midway between drains.

(ii) *Viticulture*

For the 1961 harvest in Sunraysia, a potential dried sultana yield of 35 cwt per acre has been forecast. This is based on a bud fruitfulness of 57.9%. The sampling method has been shortened, only the buds in positions 4, 9, and 14 being collected.

A potential yield of 35–36 cwt per acre had been predicted for the 1960 sultana harvest. Although final yield figures are not available, it is certain that this prediction was not realized. The chief contributory factors appear to have been abscission of whole bunches at bud burst, heavy shedding of berries shortly after flowering, and retarded berry growth after a January heat wave.

A vine-shading experiment has been concluded. Shading for 14 weeks caused a big reduction in fruitfulness, while smaller reductions followed shading for 4–6 weeks during the period from November 10 to December 22. Shading for only a fortnight within this period, or for longer times outside it, was without effect.

Sultana buds covered with aluminimum foil during certain periods again showed reduced fruitfulness. A total of 15 different periods of covering were used. In general, with buds covered from October 28 onwards, the longer the period of covering, the greater the reduction in primordium size and subsequent fruitfulness. For a fixed period of covering, the earlier the treatment, the greater the effect on primordium size and fruitfulness.

At weekly intervals, sultana buds were dissected over the period November–January, inclusive. Leaf primordia and bunch primordia were weighed on a microbalance. Fruitful buds were found to contain larger leaf primordia than did unfruitful buds. Leaf primordium weight per fruitful bud positively correlated with bunch primordium weight.

A general description of dormancy in the sultana vine has been developed, and related to time of bud burst by a regression on temperature summations, and by a field trial heating vines with infrared lamps. Changes during dormancy usually occur in two stages — early June to the third week in July, and early August to bud burst. The relation that these two periods bear to one another and to time of bud burst is determined by weather conditions. A highly significant multiple regression relates the sum of maximum temperatures from August 9 to bud burst with the sum of minimum temperatures from June 11 to 17; of maximum temperatures from June 23 to July 2; and of minimum temperatures from July 3 to 18. For these three winter periods, cold weather in the first and last, and warm weather in the second, delay bud burst.

The distribution of fruitful buds on the canes of a number of wine and table-grape varieties is still being investigated. In some of these varieties, the individual curves for total bunch primordium weight per bud position agreed very closely in the 1958 and 1959 seasons. In other varieties, such as Pedro, Red Malaga, and Touriga, the shapes of the curves were similar, but the levels of fruitfulness differed, Red Malaga being higher in 1958, the other two higher in 1959.

The experiment comparing the fruitfulness of sultana canes arising from 2-bud spurs, 8-bud canes, and 14-bud canes with various degrees of bud removal has been completed. The lengths of the two canes from the last buds on each side of the bearer, and the total weight of bunch primordia per cane were determined in each case. The two canes from the one type of bearer always behaved alike, even when they were as far apart as buds 1 and 14 (on canes with all other buds removed), while there were considerable differences between canes from different types of bearer. Canes arising from buds 13 and 14 of 14-bud canes were the shortest and least fruitful; canes arising from 2-bud spurs were the longest, and, with the canes from buds 1 and 14 of 14-bud canes with all other odd buds removed, the most fruitful.

Zante currant vines sprayed with gibberellic acid at a concentration of 20 p.p.m. again yielded as well as cinctured vines. Gibberellic acid treatment produced bigger berries, while cincturing gave better setting. With sultanas, both gibberellic acid at 20 p.p.m. and 2,4-D at 7 p.p.m. increased berry size.

Further results from the trial with Bruce's Sport, a natural mutant of the sultana, suggest that although this variety is more sensitive to chloride and boron toxicity than the normal sultana, it can yield at least as well when suitably pruned.

A replicated trial in which comparisons are being made between five Gordo selections is now approaching full bearing. In the past season, the leading selection yielded more than 3 tons of dried fruit per acre, about 20% more than the lowest-yielding selection.

In association with the Division of Plant Industry, an attempt has been made to produce mutations in the sultana vine affecting disease resistance, growth, and fruiting behaviour. Single-bud sultana cuttings were irradiated with various doses of gamma rays at the Atomic Energy Commission's establishment at Lucas Heights. There is already evidence of one possible mutation amongst those vines grown from the surviving buds; this is an alteration in the tendril pattern along the shoots.

Satisfactory control of summer weeds under currant vines was obtained with "Monuron" and "Diuron" at 1¼ lb per acre. These applications had no detrimental effects on the vines.

(iii) *Plant Nutrition*

Long-established field fertilizer trials on sultanas are being continued. In all trials except one, dried fruit yields were considerably lower than in 1959. This was probably due to seasonal conditions.

A trial has been in progress since 1938 to compare the effects on sultana yield of the following treatments: nitrogen, phosphorus, and green manure. In recent years, phosphorus has tended to depress fruit yields. It now appears that phosphorus (as superphosphate) induces a zinc deficiency, which can be corrected by spraying with 20% zinc sulphate.

There were no responses this season, either at the Research Station or Woorinen, to winter applications of nitrogen to sultana vines.

Water-culture techniques are in use to study the fertilizer requirements of sultana vines, with special reference to nitrogen, phosphorus, and potassium. In a trial of various cultural practices — ordinary cultivation, no cultivation (weeds controlled by spraying), permanent cover of white clover, and straw mulch — the mulch (now in its second year) reduced the 1960 yield by about a quarter, compared with the other treatments, which yielded similarly.

(iv) *Vegetables*

Fifteen lines of glass-house tomatoes were tested in a replicated trial to find which parents gave most hybrid vigour in the F_1 generation. Five of the F_1 hybrids produced high yields of good quality fruit.

Cooperation with the Division of Plant Industry, Canberra, has been maintained in the large-scale testing of tomato mutants. Several thousand irradiated seeds were sown in nematode-infested soil to produce 56 plants with high nematode resistance. Seed from these was collected for further tests.

Agronomic data were assembled on tomato plants of the South Australian Dwarf variety grown from irradiated seed. Three of the lines yielded twice that of the control plants for the first two pickings, while total yields were equal to that of the controls. Further trials will establish the possible existence of mutations for earliness of ripening.

(v) *Cotton*

Five varieties of cotton imported from U.S.A. by arrangements through C.S.I.R.O. Plant Introduction Section were sown in trial plots in the Sunraysia district in 1959 under special conditions for observation agreed on by the Commonwealth Department of Health. One of these, Pope, reputedly a prolific yielder, gave an excellent crop assessed at approximately 3600 lb per acre of seed cotton.

(vi) *Nematology*

Using nematode eggs sent from Merbein, a resistant vine rootstock, Dog Ridge, was inoculated at the laboratories of the Division of Plant Industry, Canberra. No galls developed on the vines, but tomato plants used as controls were severely galled.

In August 1958, part of a plot of unthrifty and dying Grenache vines was treated with a nematocidal soil fumigant. The vines in the remainder of the plot acted as controls. Since then, the treated vines have shown vigorous growth and well-developed fibrous root systems. Fibrous roots in the control vines are virtually absent.

Nine varieties of soybean seed supplied by the Cunningham Laboratory were found to be susceptible to *Meloidogyne javanica*.

Several generations of seed from the Merbein line tomatoes were tested for nematode resistance. All generations of seed appeared equally resistant to selected nematode strains, indicating that resistance has not been lost through selection in the successive generations.

Experiments have been completed on the growth responses of nematodes parasitizing tomato plants deficient in a single nutrient element. When nitrogen is lacking from nutrients supplied to tomato plants, *M. javanica* grows more quickly than in tomatoes on full nutrient. This effect is also noted, in a lesser degree, in the absence of iron, magnesium, and potassium.

Work is continuing on aspects of the attractiveness of various roots to nematodes. Carbon dioxide bubbled into diluted agar proved attractive to various species of nematodes. These included *M. javanica*.

(vii) *Fruit Processing*

The fruit-dipping oils currently available were again tested under laboratory conditions. A preparation which may be manufactured in 1961 was also tested. The performance of all oils was up to standard. A field trial of the new oil was also satisfactory.

Use of specially constructed plastic cells has facilitated the measurement of permeability of skin segments of sultanas both before and after treatment with dipping solutions. Permeability increases after dipping-oil treatments have ranged from 28 to 140%.

Further investigations have confirmed a previous report that Walthams are the main source of hollow seeds in raisins. The incidence of hollow seeds in both Waltham and Gordo grapes is not diminished by treatment of the freshly pruned vine with zinc to control possible zinc deficiency. Hollowness of seed is detectable quite early in the season, and whereas anything up to 6% of the seeds of the Gordo may be hollow, a figure of 20% is not uncommon in the Waltham, and percentages up to nearly 50 have been found. Hollow seeds cause difficulties in de-seeding processes.

A rack dehydrator (donated by the Department of Primary Industry, the Commonwealth Dried Fruits Control Board, and the Australian Dried Fruits Association) was modified late in the season to conform to final specifications which emerged from previous investigations. A short trial run of the modified equipment at the Research Station was followed by strengthening of certain parts and subsequent endurance testing which gave satisfactory results.

As in the previous year, harvest conditions in 1960 were very satisfactory for grapes. Maturometer tests showed that skin condition remained good until late in the season.

Searches have been made for a more satisfactory type of moisture meter for dried vine fruits than the Calipco instrument. Equipment is desired that is direct reading, doing away with the use of earphones, and that can handle a sample without prior mincing. The Dried Fruits Processing Committee, of which the Officer-in-Charge, Commonwealth Research Station, Merbein, is Chairman, has made a survey of instruments which could be suitable. Two such have been examined at the Research Station. The Victorian Dried Fruits Board is also interested in this enquiry.

Investigations have continued on the entry of grit into dried vine fruits and its removal by washing.

3. Griffith

(i) *Soil Physics*

Records were continued on the occurrence of peak flows from a number of drainage systems. During the dry winter of 1959 no flows above the design capacity were recorded. Maximum discharge rates in summer, due to irrigation, were below the design discharge rates. This investigation continues as a joint project with the Water Conservation and Irrigation Commission of New South Wales.

To study reclamation under natural conditions spring, summer, autumn, and winter samplings of salt movement on a tile-drained plot were continued. It was found that no permanent reclamation is feasible by this process and the next step will therefore be leaching with irrigation water during the coming irrigation season.

As there appears to be contradictory evidence concerning the depth of control of saline ground waters in heavy soils, a large number of tensiometers were installed on a heavy rice soil, and heavy, intermediate, and light-textured orchard soils. The tensiometers were inserted to varying depths between the water-table and root zone. Records are made of moisture and salt contents, and potential gradients.

In situ measurements of capillary conductivity are made in two ways: firstly, by measuring the downward drainage rate and tension gradients on bare plots that are initially saturated and protected from evaporation; secondly, by measuring the rate of inflow into a modified tensiometer, attached to a portable vacuum pump.

(ii) *Plant Physiology*

(1) *Plant–Water Relations*.—Studies of three species of *Atriplex* (saltbush) which are typical for the inland environment have been continued. These studies have related growth and nutrient content of plants growing naturally in the Hay region of New South Wales to soil and climatic factors of their environment.

Remarkable ability has been shown by all the species to maintain a high protein content in the face of salinity and moisture stress of a severe character and to withstand extremes of temperature. Glass-house work has been undertaken to elucidate the mechanisms involved. It was found that *Atriplex nummularia* (old-man saltbush) grew rapidly and was unaffected by concentrations of sodium chloride equivalent to sea-water in the soil moisture when the soil was at field capacity.

The effects of moisture stress on the apical development of *Lupinus albus* (the white lupin) have been found to parallel those noted earlier, where apical development was inhibited. The effects of salinity have also been followed.

Weighbridge studies have been initiated to evaluate the factors controlling the rate of water loss in *Atriplex nummularia* and to elucidate the mechanisms involved.

(2) *Salinity Effects on Plant Growth*.—A wide area of Australian soils where there is no outlet drainage contains salt which readily appears when the land is subjected to irrigation. A better understanding of the reasons for salt tolerance will enable a suitable spread of plant growth to be made into salty areas. Work on this subject was continued with barley as a test plant. It was found that in general *Hordeum distichum* varieties were more salt sensitive than *H. vulgare* varieties. Three *H. vulgare* varieties were grown till maturity. Dry matter production was reduced by sodium chloride in all these varieties. However, one variety, which absorbed more chloride and sodium and less potassium than the other two, suffered greater decreases in dry weight.

Grain production was very small in this variety, but in the more tolerant varieties grain weight ratios were similar in control and sodium chloride treatments.

(3) *Flood Injury to Plants.—Prunus persica, Helianthus annuus, Nicotiana tabacum,* and *Salix babylonica* have been selected as experimental material to investigate the ill effects on plants resulting from waterlogging of soils. This problem is of importance to the Murrumbidgee Irrigation Areas, particularly since half of the peach tree plantings were lost after the 1956 floods.

Because of the nature of the early symptoms associated with waterlogging (epinasty, initiation of adventitious roots, callus formation, and stem-thickening) it is possible that the level of endogenous auxin within the plant is raised. The experimental work in hand is designed to check this possibility.

(4) *Plant Nutrition — Citrus.*—The factorial field experiment with citrus was continued. High nitrogen levels have a depressing effect on fruit quality, and the interaction between nitrogen and phosphorus is of special interest. It was established that the continued use of ammonium sulphate caused a decrease in the availability of soil phosphorus, associated with changes in the aluminium fraction of the soil.

Strong evidence of a direct nitrogen effect was obtained in a study of the development of the Washington Navel orange. Major differences in fruit quality did not develop until rather late in the life of the fruit (end of March).

A more precise assessment of the effects of nitrogen and phosphorus on fruit quality was made in a glass-house experiment with fruiting Navel orange cuttings. Under conditions of ample nitrogen supply, the proportion of peel and rag in the fruit was greatly decreased by increased phosphorus levels.

Knowledge of the developmental physiology of citrus, both in the vegetative and fruiting stages, is rather scant, and the factors controlling the change from one to the other are not understood. A study is being made of the development of Navel orange cuttings over the vegetative period preceding flowering. Concurrent experiments will elucidate the effect of day length on development. Other work is aimed at studying the development of the fruit under different levels of nitrogen and phosphorus supply.

(iii) *Physics and Engineering*

A spectrometer equipped with an integrating sphere is in use for transmission and reflection measurements on plant material and other diffusing specimens. Measurement of the absorbance and reflectance with varying wavelengths should help in evaluating the energy balance at the leaf surface. Initial trials do not seem to indicate much difference between Australian species with drought-resistance qualities and those species which are restricted to high rainfall areas.

Preliminary work on the vacuum bench has produced samples of thermopiles for use in measuring gross radiation, net radiation, and other factors concerned with the energy balance of plants in respect of water loss. Some of these instruments are radiometers giving integration with time without the use of outside power supplies.

As the Station is in a relatively remote inland area, sufficient standards are being assembled to help maintain accuracy over a range of fundamental measurements.

6

Animal Research Laboratories

The largest group within C.S.I.R.O. studying the breeding, health, and husbandry of animals, was formerly the Division of Animal Health and Production. Following the retirement of Mr. D. A. Gill as Chief, this Division has been reorganized as three new Divisions which collectively form the C.S.I.R.O. Animal Research Laboratories. These are:

The Division of Animal Genetics of which Dr. J. M. Rendel has been appointed Chief.

The Division of Animal Health of which Dr. T. S. Gregory has been appointed Chief.

The Division of Animal Physiology of which Dr. I. W. McDonald has been appointed Chief.

The research programs of the three Divisions are coordinated by an Animal Research Committee, under the chairmanship of Dr. Rendel.

The research projects of these three Divisions which comprise the Animal Research Laboratories are described in the following Chapters 7, 8, and 9.

Much of the work of the Animal Research Laboratories forms part of the Organization's integrated program of research on problems of the sheep and wool industries. This program includes every phase of wool production: soils, pastures, nutrition, genetics, animal husbandry, wool processing, textile manufacture, and the exploitation of by-products.

Research on soils, pastures, and related matters affecting the pastoral industries is carried out by the Division of Soils (*see* Chapter 2); the Division of Plant Industry (*see* Chapter 3); the Division of Tropical Pastures (*see* Chapter 4); and the Division of Entomology (*see* Chapter 11).

Work on the sheep itself is undertaken within each of the Divisions of Animal Genetics, Animal Health, Animal Physiology, and Biochemistry and General Nutrition (*see* Chapters 7, 8, 9, and 10). The Division of Mathematical Statistics is closely associated with various animal breeding investigations currently in progress. The Division of Entomology undertakes research on the sheep blowfly (*see* Chapter 11).

The Wildlife Survey Section (*see* Chapter 12) undertakes study of methods of controlling those species of wildlife which compete for nutriment with the grazing animal.

The Organization's work for the cattle industry is carried out chiefly in the Divisions of Animal Genetics, Animal Health, and Animal Physiology (*see* Chapters 7, 8, and 9). The Division of Biochemistry and General Nutrition studies problems of nutrition of the ruminant animal (*see* Chapter 10).

The Division of Entomology is concerned with research on the cattle tick (*see* Chapter 11).

The Divisions of Soils, Plant Industry, Tropical Pastures, Entomology, and Land Research and Regional Survey, and the Fodder Conservation and Engineering Sections all undertake research projects which relate to pastures and fodder for the cattle industry.

7

Division of Animal Genetics

1. General

The Division of Animal Genetics is one of the three Divisions of the C.S.I.R.O. Animal Research Laboratories. It consists of the Animal Genetics Laboratory and the animal breeding group at the University of Sydney; the F. D. McMaster Field Station at Badgery's Creek, N.S.W.; the National Field Station, "Gilruth Plains", Cunnamulla, Qld.; the National Cattle Breeding Station, "Belmont", and the Cattle Research Laboratory, Rockhampton, Qld.; and the Poultry Research Centre, Werribee, Vic. The headquarters of the Division of Animal Genetics are in the grounds of the University of Sydney, Parramatta Road, Glebe, N.S.W.

The research programs of the Division include: fundamental problems in genetics; application of genetics to animal breeding; genetical and physiological aspects of the phenomenon of heterosis; and study of those characters which allow beef cattle to thrive under hot conditions. Also under investigation are: wool production; occurrence of twinning and meat production in Merino sheep; egg production in poultry; and selection of dairy cattle to produce a breed suitable for tropical conditions.

The Division of Mathematical Statistics is closely associated with the various animal breeding research projects currently in progress.

Officers of the Division of Animal Genetics have assisted the Universities of Melbourne and Sydney with courses of lectures on genetics and animal breeding. The Division has continued to assist in the training of visiting F.A.O. and Colombo Plan students, who have spent varying periods at one or more locations in the Division.

An important development during the year at the Animal Genetics Laboratory was the installation of an electron microscope purchased in collaboration with the Division of Food Preservation and Transport. Three students were reading for their Ph.D. degree in the Animal Genetics Laboratory this year, and two of these have now completed their studies.

Improvements effected during the year at the McMaster Field Station include the erection of a two-stand woolshed, a 1000-bushel grain silo, subdivision fencing, and a further eucalypt plantation.

A Visitor's Field Day was held at the National Cattle Breeding Station in April 1960, which enabled the Division's cattle breeding projects to be demonstrated to cattle breeders and others.

A useful addition to the facilities at the Poultry Research Centre, Werribee, has been the construction of a large constant-temperature chamber designed to hold 576 chicks. This will facilitate current research projects on young chickens. A second chamber without temperature control has also been built, which will hold 192 adult layers in single bird cages.

Grateful acknowledgment is made of all those individuals and associations of individuals who have contributed in various ways to assist the Division in its program of research.

The work described below under "Animal Genetics" is undertaken in the Animal Genetics Laboratory (formerly the Animal Genetics Section) which is housed in the Zoology Department, University of Sydney.

2. Animal Genetics

(1) *Genes, Chromosomes, and Other Granules.*—A necesary preliminary to the study of relationships between viruses, antibodies, and cellular synthesis, including chromosome structure on the one hand and cell structure on the other, has been the study of ultrastructure of nuclear (chromosal) filaments, and the ribonucleoprotein granules of the cytoplasm of protein-synthesizing cells. In the latter project use of imbedding media permeable to aqueous solutions permits rapid selective staining of electron microscope sections with particular metallic solutions. The granules appear under such conditions to consist of an inner core, lanthanum stainable, and an outer cortex stainable with numerous protein stains. This study is by no means completed, but it suggests that the ribonucleic acid (RNA) is organized as a complex filment in the centre of the granule with a (possibly multiple) protein shell around it. Digestion with pappain removes the stainability of the outer shell, further supporting the interpretation of protein nature.

Studies have continued on gene mutation. That mutations occur when the chromosome is in a two-strand state is indicated by ultraviolet irradiation experiments with a histidine mutant of *Neurospora*. Of 16 ultraviolet-induced back-mutant colonies (of $hist \rightarrow hist^+$), each of which had arisen by mutation in a single haploid nucleus, nine proved to be heterokaryons having two types of nuclei. (A colony of *Neurospora* is a syncitium throughout which nuclei may freely migrate. In a heterokaryon this syncitium contains two or more genetically different populations of nuclei.) The ratio of the two types of nuclei was 1 : 1. There is evidence from elsewhere to suggest that the nuclear ratio is determined solely by the relative proportion of nuclei present when the heterokaryon first forms and is independent of selective forces. It follows that the chromosomal strand was double when the mutation occurred.

Some of the heterokaryons had a histidine component resembling the parental histidine stock in growth behaviour and in its pattern of accumulation of imidazole derivatives, together with a *hist*$^+$-like component resembling the original *hist*$^+$ from which the *hist* mutant originated. One heterokaryon consisted of a *hist* component and a *hist*$^+$ component which had acquired a requirement for the vitamin pantothenic acid. Similarly, in another heterokaryon the *hist*$^+$ component had picked up another (unknown) growth requirement. Two other heterokaryons had relatively normal *hist*$^+$-like components together with phenotypically different *hist* components. Thus it seems that the events leading to back mutation of *hist* to *hist*$^+$ in one strand also resulted in the simultaneous occurrence of a mutation in the other strand.

Analyses of the results of the first 30–40 generations of selection for the two characters, abdominal bristle number and body weight, in *Drosophila melanogaster*, referred to in the previous report, have been completed.

Diallel crosses in the Oregon wild-type laboratory stock, which was the base population for the selection work, showed a heritability from 20 to 25% for the number of bristles on the fourth and fifth sternites. There was no non-additive genetic variation. Heritability, estimated from diallel crosses in the 13th, 23rd, and 33rd generations of selection as well as in the base population, at no stage predicted accurately the change in bristle number accompanying future selective breeding. The additive genetic variability declined rapidly to low levels or zero depending on the selection line. At the same time, a large amount of non-additive genetic variability appeared. In spite of the absence of additive genetic variation selective breeding was successful in all lines for many generations.

Diallel crosses in the base population for body weight showed an absence of additive genetic variability, a high proportion of non-additive genetic variation, and considerable genotype-environment interaction. Here again selective breeding was successful in all lines for many generations in spite of the absence of additive genetic variation. Genotype-environment interactions of varying degree were detected readily in the selection lines. Three different types of culture conditions were used for this purpose. The repeatability of response in replicate lines was higher for both characters from this population than others reported in the literature. The direction and extent of asymmetry of response between high and low directions were also different from other published work. It is suggested that these aspects of the response picture are characteristic of a particular population, and cannot be predicted by conventional analyses of genetic and phenotypic parameters. Correlated responses in fitness body weight in the bristle lines, bristle number in the body weight lines, time of development, sex ratio, and mutation rate were also observed. Differences between replicates, asymmetry of correlated response and, in particular, inconsistencies in the behaviour of the bristle number–body weight–time of development relationship in the two main experiments, are interpreted as departures from prediction which might not be entirely explained as genetic sampling effects. Selection was continued in the four bristle selection lines, till the 73rd generation, after which they were maintained as relaxed lines by random mating. Selection was ineffective in both high lines and one low line from about the 35th generation. The other low line continued to respond slowly till about the 55th generation, its final level being almost the same as the first low line. Relaxed lines were taken off the selection lines at the 36th generation and carried as such till the 73rd generation. Selection has just been recommenced. The two high lines remained at their selected level during these 37 generations of relaxation, but the low lines regressed some 25–30% from their selected level towards the level of the unselected base population.

The body weight selection lines have been maintained as relaxed lines with random mating from the 40th to the 77th generations. All lines appeared to remain at their selected level for at least the first 10 generations of this period of relaxation.

A strain of *Drosophila* has been developed in which the dominant sex-linked gene, hairy-wing (which normally increases the number of bristles over the body), and the recessive sex-linked gene, scute (which normally reduces the number of bristles over the body), have apparently been combined as the result of a very rare crossover. Initially, the expressivity of scute in this strain was poor and of hairy-wing quite good, with reference to the main effect of each gene, i.e. on scutellar bristle number and on the hairiness of the wing respectively. Selection for expression of scute enabled the expressivity of scute to be improved but resulted in a decline in expressivity of hairy-wing. For the abdominal bristle character, there has occurred an interaction between the two genes, so that this strain has an abdominal bristle number not very different from an average wild-type stock. The effect of this epistatic combination on the variability of abdominal bristles has not yet been analysed, nor has the effect of selection for better expressivity of scute on the epistatic situation for abdominal bristles.

(2) *Immunogenetics.*—The antigenic complexity of bovine plasma albumen and bovine gamma globulin is being studied by agar diffusion, electrophoresis, and ultracentrifugation. Results emphasize the sensitivity of immunological specificity. Bovine ribonuclease has been found to be antigenic and a demonstrable ananphylactic reaction was found to doses as low as 0.5 μg. Physiological aspects of anaphylaxis are being examined with some emphasis on the work of mast cells during shock.

The surface antigens of paramecium offer interesting material for further studies on the inheritance of antibody response. Recent studies elsewhere on methods of extraction and chemical characterization make these antigens unique with respect to work on mice, since they can be assayed with very small volumes of antisera.

(3) *Radiation Genetics.*—The feasibility of using X-ray induced mozaics to allow measurement of mutation rates is being examined in a preliminary series of experiments. The aim is to estimate the regression of frequency of "mutant" areas on age at irradiation. This regression should, if mozaicism is nuclear in origin, be exactly determined by the rate of increase in number of sensitive nuclei, which should be given by the number of epithelial cells. If mozaicism is not nuclear in origin, but dependent on cytoplasmic self-replicating structures, which arise after development has been initiated, e.g. Medawar's pigment granules, then the regression should have its origin at a zero frequency of mozaicism, which is located at the time of origin of the extra-nuclear particles.

These experiments, based, at present, on numbers in the range 10^3–10^4, will need to be extended to numbers in the range 10^5–10^6.

(4) *Leukaemia in Mice*.—Studies commenced on the nature and transmissibility of radiation induced leukaemia in mice. The Kaplan induction has been used in C_{57} mice, and the leukaemic cells are passaged at about 12-day frequency. Further successful transfer has been effected in random-bred mice, extending into hosts as old as 15 days — utilizing phenomena of graft tolerance. The leukaemia, which is transferable by cell-free homogenates, attributed to a virus-like particle, has been examined electron microscopically and it is found that the large leukaemic lymphocytes contain in about 5–10% of cases, virus-like bodies of 0.1–0.2 μ in diameter with a single membrane containing a large, dense, uranium-staining "nucleoid" which is often filamentous in character. Further, a proportion of these particles appear to be undergoing simple binary fission.

(5) *Myxomatosis*.—Study of microscopic and submicroscopic changes in the myxoma infected rabbit revealed an unexpected complex growth cycle in the virus. Early stages closely resemble many other viruses, but develop to a terminal stage reaching $\frac{1}{2}$–1 μ in diameter, which in turn develop small elementary bodies within them which are eventually released. These larger terminal stages are observable in the optical microscope, and are Feulgen positive, confirming the suggestion prompted by electron microscopy that the outer zone of these large bodies contains deoxyribonucleic acid.

A complicating factor in the interpretation of the myxoma cycle is the occurrence in small numbers in the spleens of all normal rabbits, of cells not dissimilar to myxoma cells. Further, these contain bodies indistinguishable from myxoma virus stages. No substantial abnormality appears to result from these, and they do not give evidence of cytotoxicity. However, when tissues from normal rabbits are transferred into culture media, rapid growth of the virus-like bodies occurs, resulting in substantial transformation to myxoma cell cytology, and eventual cell death. When the skin of a normal rabbit is scarified, less marked but similar transformations are observed in the actively proliferating fibroblasts of the scar.

Study is continuing of the inheritance of resistance to myxomatosis. The genetic parameters underlying this resistance are being estimated by the intrasire correlation method using survival time as an index of resistance. Results, based on 620 offspring from 128 dams and 32 sires, give an estimate of h^2 on the sire component of 25% and on the dam component of more than 100%. This very high dam component indicates a strong maternal effect, which, since it is higher in dams of high selection grade, suggests a greater contribution of antibodies to the offspring by these grades. This possibility is being tested. The sire component is independent of any maternal effects, is subject to a high standard error, and will require more data for substantiation. However, it is probably near the true value, and fits reasonably the response being obtained to selection.

Results from a colony of wild rabbits maintained in a paddock at Prospect indicate that the virulent Glenfield virus is capable of approximately 100% case mortality in rabbits with quite a high genetic resistance to the milder KM_{13} virus strain.

(6) *Mathematical Genetics.*—The simulation of genetic systems on automatic electronic computers has been extended by a program allowing examination of the effects of selection on complex interaction systems, showing that selection against extremes will have little effect on gene frequencies in large populations; any reduction of phenotypic variability is effected primarily by modifications of the system of genetic interaction, if this is modifiable.

The extension of the SILLIAC computer to include a magnetic tape secondary "memory" is being utilized to allow simulation of different types of interaction, allowing decision on the effectiveness of selection as a means for evolving systems of interaction.

Sheep.—Selection experiments continued on the ratio of secondary to primary follicles, and on the density of follicle groups. Results, although not decisive, support the hypothesis that quantity of wool is determined primarily by the density of primary groups and dimensions of the wool fibres by the ratio of secondary to primary follicles.

Work on the mozaic fleeces is being extended to different levels of feeding, allowing comparison of the sensitivity of different kinds of wool to altered levels of feeding.

A study has been made of blood supply to the skin of sheep embryos (81 days' gestation). The embryos belonged to two groups: Fleece + and Fleece −. At this stage every central primary follicle is surrounded by a capillary blood vessel ring, an anlage of its future blood supply. No detectable difference has been found in blood supply pattern between the two groups.

(7) *Sweat Glands and Hair.*—As part of a general study of the relationship between skin characters and production in cattle, a survey has been made of the shape and size of sweat glands in some Australian dairy breeds. A new measurement, the length–diameter ratio, has been introduced to express the shape of the sweat glands numerically. Although the volume of sweat glands varies throughout seasons, the characteristic shape, expressed as length–diameter ratio, does not.

Examination of about 350 Jersey cattle has shown that the small baggy type of gland is a characteristic of the breed. About one in 30 Jerseys has sweat glands comparable in size with those of Zebu and, consequently, a similar honeycombed skin structure. There is probably a positive correlation between sweat gland size and milk production. This finding has to be tested on a larger number of animals.

A survey has been undertaken of sweat glands and skin structure in the following breeds of cattle from Scotland: Aberdeen Angus, Ayrshires, Dairy Shorthorn, Friesian, Galloway, Hereford, Highland, and Jersey. The sweat gland shape can be regarded within certain limits as a breed characteristic. The longest and most coily glands have been found in Aberdeen Angus and Galloways. The Ayrshire cattle have surprisingly large glands which are very variable in shape. Some animals resemble in their gland structure Zebu × European breed crosses.

The effect of temperature stress on coat characters has been examined in actively growing mice. The animals were kept for 4 weeks at constant temperature of 98°F, and their litter mates at 68°F as controls. At the end of the treatment the controls were about 30% heavier. The hair length and hair diameter in treated animals was about 9% less than in controls.

3. Animal Breeding

The projects described below are undertaken by the animal breeding group based at the McMaster Laboratory in the grounds of the University of Sydney. The major part of the research of this group involves sheep breeding investigations, and experimental flocks for this work are maintained at Cunnamulla, Qld., and at Armidale, N.S.W.

(i) *Heredity × Environment Interactions*

Matings have been completed in the experiment designed to compare the progeny of the same ram in different environments. Analysis of two-tooth data from progeny born in 1956 have shown no important ram × environment interactions. A new experiment was commenced with matings in 1960 in which selection for high clean wool weight will be carried out in each of two environments, Cunnamulla and Armidale. The sheep will subsequently be interchanged to check their performance in the other environment.

(ii) *Selection of Individual Sheep*

(1) *Results of Selection for Clean Wool Weight.*—Response to selection for high clean wool weight in medium Peppin Merinos has continued, the difference between the selected group and the unselected controls in February 1959 being 1 lb of clean wool per head. Increases in number of fibres per square inch of skin and in staple length have, as before, made the greatest contribution to increases in wool weight. There is still a negligible difference in body weight, although no attention has been paid to this character. Selection for high clean wool weight has led to a substantial increase also in wool weight per pound of body weight. Although fleeces in the selected group were in 1959 actually finer than in the control group, the crimp number was again slightly lower. A second batch of fleeces from each group has been sent to the Division of Textile Industry to check on their processing performance. Matings in 1958 and again in 1960 had to be abandoned because of drought conditions.

(2) *Estimates of Genetic Parameters.*—Estimates of heritability and genetic correlations have now been calculated for wool weight and a number of other characters. The heritability estimates range from 0.3 to 0.6 for the various characteristics. Negative genetic correlations greater than 0.5 were found between crimp number and three other characteristics (clean wool weight, staple length, and percentage yield), between wrinkle score and staple length, and between fibre population density and fibre diameter. A positive genetic correlation greater than 0.5 was found only for clean wool weight and percentage clean yield.

(3) *Correlated Responses to Selection.* One of the uses of genetic correlation estimates is to predict the change which will take place in a character due to selection for another which is correlated with it. Pairs of families have been established by up-and-down selection for single characters, each pair showing a marked difference in the character under selection. Predicted changes in correlated characters have been compared with those observed, and in most cases the agreement has been remarkably good.

(4) *Selection for Twinning.*—Merino ewes selected initially for bearing twins have continued to give a better reproductive performance than those selected initially for bearing singles. Over six matings the difference has been 26% in lambs dropped and 14% in lambs weaned (both as a percentage of ewes mated). Unclassed ewe progeny born to the twin group have averaged 18% more lambs dropped and 16% more lambs weaned than similar ewe progeny born to the singles group.

In 1959, a commercial breeder donated a quintuplet Merino ram from a flock which had been selected for multiple births. This ram was mated to 12 maiden Merino ewes purchased from the same property, 19 lambs being dropped and 17 weaned. These results hold promise that some response can be expected to selection for multiple births, at least in some environments.

(5) *Selection for Meat Production.*—Selection groups for good and poor mutton type were begun at Armidale in three Merino strains in 1958, selection being based on visual scores and the ratio of body weight to elbow-coronet length. Progeny born into the up-lines in 1958 were generally heavier at birth and at weaning than those born into the down-lines, and had a slightly higher mutton score at 12 months of age.

(iii) *Theoretical Studies*

(1) *Selection for Lifetime Performance in More than One Character.*—Methods of selection for more than one character have in the past been discussed mainly in relation to genetic improvement. Selection for lifetime production is also important, and an index has been developed for this purpose.

(2) *Errors of Genetic Parameters.*—Estimates of error have been obtained for genetic partial regression coefficients and for predictions of genetic change due to selection.

(3) *Efficiency of Large-scale Artificial Insemination Operations with Sheep.*—Statistical techniques have been developed for checking the observed against the predicted numbers of ewes on heat for the first time or returning to service. An assessment of the significance of departures from expectation will indicate the need for replacing sires, checking techniques, or varying the length of the mating period.

(iv) *Genetics of Fleece Structure: Crimp-Diameter Studies*

Matings were begun in 1958 with animals selected for different combinations of crimp and diameter — high crimp number with high fibre diameter and low crimp number with low fibre diameter. Measurements on progeny born in 1958 have indicated that selection has been effective in producing a difference between the two groups.

4. Cattle Breeding, Queensland

The research described below is undertaken at the National Cattle Breeding Station, "Belmont", and at the Cattle Research Laboratory, Rockhampton, Qld.

The National Cattle Breeding Station, of 7000 acres, is located 20 miles north of Rockhampton where the average rainfall is 38.95 in. The property was purchased by the Australian Meat Board in 1952 to provide facilities for studies on the adaptation of cattle to hot environments and was occupied by C.S.I.R.O. in 1953. The associated Cattle Research Laboratory is at Rockhampton. The present program concentrates on two breeds of British cattle (Herefords and Shorthorns), crosses between those breeds, and crosses of those breeds with Zebu types represented by the American Brahman and the Afrikander. The number of cattle on "Belmont" at March 31, 1960 was 1309.

Despite a fairly difficult season with near-drought conditions from July to October, the health and condition of all stock remained satisfactory. Some 300 head were disposed of during the year, including 12 stud Afrikanders and Brahmans sold by public auction. Two Afrikander bulls and four Afrikander × Shorthorn first-cross bulls were sold to the Department of Territories, New Guinea.

(i) *Crossbreeding — Rates of Growth*

The rates of growth of eight first crosses between Hereford, Shorthorn, Brahman, and Afrikander breeds have been studied over four generations. Birth weights of calves varied according to breed, the Brahman crosses being the heaviest at an average of approximately 90 lb and pure Shorthorn and Afrikander crosses lowest at about 64 lb. Observations confirmed that Brahman and Afrikander bulls mated with Hereford or Shorthorn females give progeny which grow faster than Hereford and Shorthorn or crossbreds of these breeds.

Second-cross (F_2) progeny of Afrikander and Brahman crossed with Hereford and Shorthorn have now become available and their performances compared with first cross (F_1) of the same age, running under identical conditions, have been examined. In all instances birth weights and weaning weights of F_2's were lower but there was no consistent difference in post-weaning gain. Both the Afrikander × Shorthorn and Brahman × Shorthorn F_2's showed a very wide variation not only in body weights but also in coat type, coat colour, and conformation.

(ii) *Conformation — Carcass Studies*

From experience gained when the 1954 drop of steers was killed at comparable ages, it was decided that material for subsequent studies should be obtained from steers of approximately 1000 lb liveweight. One hundred and fourteen steers of the 1955 drop and six 1956-drop Grade Brahmans have been killed at this liveweight and the carcasses appraised and major muscles dissected and weighed. The 1955 drop represent at least nine animals of each of the Hereford, Hereford × Shorthorn, Shorthorn × Hereford, Shorthorn, Afrikander × Hereford, Afrikander × Shorthorn, Brahman × Hereford, and Brahman × Shorthorn breeds. Weights of longissimus dorsi, biceps femoris, semitendinosis, and quadriceps group of muscles from Herefords are not significantly different to the Afrikander crosses, Brahman crossbreds, and Grade Brahmans except that the Hereford has a significantly heavier longissimus dorsi muscle than the Brahman × Shorthorn. The Shorthorn and Shorthorn × Hereford have significantly lighter muscles than all breeds. There is, however, no significant difference between the Hereford × Shorthorn and Shorthorn × Hereford. Differences in conformation of the rump of Afrikander and Brahman crosses make little difference to the shape of their carcasses. Highly significant differences in dressing percentage favour the Grade Brahmans and Brahman crosses.

(iii) *Copper Supplementation of Beef Cattle*

Supplementation of breeding cows with 400 mg of copper glycinate at three monthly intervals made no difference to their breeding performance, birth weight of their calves, or the growth rate of calves to 3 months of age, although it raised the level of copper in the blood and liver. Levels of copper in the blood and liver of the calves and their growth to weaning is being followed.

(iv) *Adaptation to Tropical Environment* (*Cattle Research Laboratory*)

(1) *Thermoregulation.*—Relationships between body temperatures, respiration rates, coat characters, sweating rates, sweat glands, and growth rates are being studied on recent generations of calves at Belmont. Repetition of a previous experiment is showing that keeping the coat clipped improves growth to some extent, but it still appears that a naturally smooth-coated animal is superior to a clipped animal.

(2) *Hair Growth.*—Phases of the growth cycles of hairs throughout the year have been measured. Seasonal changes in initiation of new hairs, growth phase, quiescent phase, and other hair characters have been defined. Differences between animals in these respects are being studied. The effects of hair growth of topical application of adrenal and sex hormones are being examined. An adrenal hormone profoundly depressed initiation of new hairs.

(3) *Efficiency of Feed Utilization.*—Work on animals in metabolism cages has been started to identify, initially, the components of feed utilization responsible for different growth rates of different breed groups. These components are voluntary intake, digestibility, and storage of absorbed nutrients. Intake is controlled. Digestibility of dry matter and of nitrogen, nitrogen utilization, and body weight change all rank in the following decreasing order: Grade Brahmans, Afrikander × Hereford, Brahman × Shorthorn, Hereford. Whereas these efficiency differences have been shown, it appears likely that differences in feed intake make an important contribution to the superior growth of crossbreds at pasture.

Preliminary work for these experiments involved the selection, training, and breaking in at "Belmont" of young animals to accustom them to the metabolism cages. Of the 32 animals handled to date only one proved intractable. The relative ease with which the Grade Brahmans accepted restraint was most impressive.

(4) *β-Globulin Polymorphism in Cattle.*—Data from about 1000 artificial matings of Jersey cattle, derived from blood samples supplied by the Queensland Department of Agriculture and Stock, have been examined for relationship between

fertility and β-globulin types of bulls and cows. The main feature was that matings between like or unlike homozygotes gave better conception rates than matings involving heterozygotes.

5. Poultry Research Centre

The principal activities at the Poultry Research Centre, Werribee, Vic., involve genetical and biochemical studies on the phenomenon of heterosis. In addition, a production flock of White Leghorns, in which genetical advance is nearing the plateau stage, is being maintained for further studies. A control flock of White Leghorns, in which the number of effective male and female parents is being steadily increased, also forms part of the overall stocking of the Centre. Inbred lines, with coefficients of inbreeding approximately 80%, are being expanded principally for use in biochemical and physiological studies involving young chicks, both inbreds and incrosses.

Close cooperation has been established with the Walter and Eliza Hall Institute. Fertile eggs, from certain highly inbred lines, are made available at regular intervals for immunological studies which are currently under investigation at this Institute. It is anticipated that, in the future, special inbred lines will be developed and the particular matings involved will have, as their basis, immunological rather than production information.

During the 1959 breeding season a total of 199 sires was used and these were mated artificially to 1107 pullets. Mortality of the flock, to the end of the pullet year, was 14.4%. There were 6264 birds on the property at April 1960 including 4961 females in lay. These comprised 2381 White Leghorns, 856 Australorps, and 1724 crossbreds of various types.

In the new accommodation house built for adult laying birds, a treatment involving continuous artificial light, continuous availability of feed, and continuous noise has been imposed on the pullets, which are now laying approximately the same number of eggs in each 6 hr period throughout the day. In this altered environment selection for egg production will be made in an attempt to apply the findings on canalization of the scute phenotype in *Drosophila melanogaster* and the vibrissa number in mice.

(1) *Population Genetics*.—The production-bred flock of White Leghorns were inferior, to the extent of 10 eggs (survivors) and 12 eggs (hen-housed), when compared with the previous year's production. These figures are net after having taken into consideration the performance of the control. This line may be showing a plateau with respect to egg production. Recent estimates of heritability suggest that additive genetic variance is nearing exhaustion. The mean level of inbreeding of the flock is 25% Wright's coefficient, with a range of 23–29%.

The system of Recurrent Reciprocal Selection has proved inefficient in increasing performance when applied to the two breeds, White Leghorn and Australorp. This lack of progress could possibly be attributed to the size of the operation and would indicate that, if this method of selection is to be used, large numbers of sires have to be tested, and the size of the progeny groups should also be large.

The two synthetic lines of crossbreds maintained their production at approximately the same level as in the previous year. One line increased production by two eggs and the other had a similar decrease.

A study of heredity × environment (type of housing) interaction is nearing completion. Preliminary analyses have been carried out and the results obtained are not suggestive of significant interactions in production characters.

A theoretical study of optimum flock structure (for flocks of fixed size) to yield maximum genetic progress has received further attention and the practical information derived from this study will be available in the near future.

(2) *Avian Physiology and Nutrition*.—Work continued on the physiological basis of heterosis. Facilities for studying the nutrition of individual chickens, from day-old to 4 weeks of age, and under uniform conditions, are now available. Two main nutritional experiments have been completed.

Using purebred Australorps and White Leghorns, and their reciprocal crosses, it was shown that dietary restriction called into play adaptive responses for growth which increase the efficiency of growth. The time taken to make this response showed a heterotic relation (the Australorps required more time). In addition, efficiency after adaptation showed a heterotic relation (again the Australorps were the worst group). No dam or sire effect was apparent.

Using a highly inbred line and one of its crosses with another inbred line, it was shown that essential amino acid requirement was a complex phenomenon with no evidence for consistent response by the same individual to a range of essential amino acids.

Work on critical stages for death in embryos of inbred lines has shown eight such periods during life in the egg and one at 4–6 days after hatching.

6. McMaster Field Station

This Station, of 600 acres, is situated at Badgery's Creek, N.S.W., 30 miles west of Sydney, and is devoted primarily to breeding and genetical work on sheep, the development of a Zebu-cross dairy herd, and studies on adaptability of dairy stock to tropical conditions.

(i) *Breeding and Genetical Studies*

(1) *Inbred Flocks of Australian Merinos*.—In association with the inbreeding work on sheep an inbreeding experiment with *Drosophila melanogaster* is being undertaken. Ten lines of flies have been set up in all of which inbreeding is taking place. Five of the lines are simultaneously undergoing selection for bristle number on the fifth abdominal segment. The experiment has now reached the 40th generation. Results so far parallel those obtained from the inbred flocks of Merinos, namely, that inbreeding has not affected the non-fitness character under

observation but that it has affected fitness characters. Polyallel crossing involving all the 10 inbred lines has been undertaken. So far heterosis has not been exhibited by bristle number but there are indications that it is being exhibited by body weight.

(2) *Inheritance of Fleece Characters*.—Final collection of data will take place this year. Preliminary examination of skin biopsy material from the F_1 and F_2 generations shows that, in F_2, although variance has not increased for fleece weight, or weight of wool per unit area of taut skin, there have been very considerable increases in the variances for follicle number $(P + S)$ and fibre weight.

(ii) *Dairy Cattle Investigations*

(1) *Zebu-cross Dairy Herd*.—The nucleus herd of Zebu strains of dairy cattle (*Bos indicus*) maintained at the McMaster Field Station now consists of: Sahiwals, four males, eight females; Sindhis, six males, eight females. Other cattle, totalling 153, include Jersey females and F_1 and F_2 generations of Zebu × Jersey. A group of 32 Jersey heifers was bought during the year.

Some 20 F_1 heifers have now calved. All have been tractable and amenable to shed discipline and handling. Their milk production has been extremely variable and the proportion of low producers was very high. The culling rate for low production has been about 70%. The first two F_2 heifers were mated this autumn.

(2) *Coat Shedding Studies*.—The work on normal hair growth and shedding has been completed and will be published shortly. Collection of material in the growth and development studies with calves is continuing.

(3) *Hot Room Studies*.—Experiments commenced on the physiological responses of cattle to hot environments, with particular attention to sweating behaviour. In the first series Zebu and Zebu × Jersey animals were used. After thorough preliminary training to accustom them to the hot room environment and its associated handling one Sindhi, one Sahiwal, and two crossbred animals were held in the hot room in pairs, under constant temperature conditions of 104°F dry bulb and 82°F wet bulb. Each animal was taken into the room on 10 occasions. On five of these they had been fed during the preceding 24 hr, and during the experimental period. On five occasions they were fasted for the previous 24 hr, and during the experiment. Water was always available. Measurements of sweating rate, skin temperature, rectal temperature, and respiration were made at intervals over the 5-hr period.

The mean values of all characters measured were higher for the fed animals, indicating that feeding contributes to the heat load. Within the range of rectal temperatures observed in these experiments it appeared that sweating rate did not depend on rectal temperature, but, on the other hand, it had an influence on it. Skin temperatures were found to be not solely dependent on environmental temperature — they were characteristic of the individual animals.

In a second series of experiments, in which Jerseys as well as the other types of animals are being used, the reaction of the animals to three types of environment is being compared. The environments are: hot room (104°F dry bulb, 82°F wet bulb); ante-room (temperature range 60–75°F); the open field. In pairs, the animals are being subjected to the three enviroments in rotation. The experiment is not complete. However, data so far collected on sweating rate and skin temperature show a definite relationship. With low, but rising, skin temperatures sweating rate remains fairly constant until a point is reached at which there is a sudden large increase. With Zebus and crossbreds the increase appears to occur at a higher skin temperature and to be of a greater magnitude than is the case with Jerseys. Further data are needed to establish the significance or otherwise of these breed differences.

7. National Field Station, "Gilruth Plains"

The National Field Station, "Gilruth Plains", is a 40,000 acre property near Cunnamulla in south-western Queensland in a semi-arid region with a mean annual rainfall of about 15 in., most of which falls in the warmer months of the year. The Station, with its 6000 sheep, mostly Merinos, is devoted mainly to large-scale breeding experiments.

The present breeding program commenced in 1947 and has proceeded uninterrupted until the drought years of 1957 and 1958. The number of ewes mated in 1958 had to be greatly reduced. The response to pastures from summer rains in 1959 was such that normal mating and lambing of all experimental flocks was resumed. Drought conditions reappeared at the end of 1959 and have since prevailed. The lambs were weaned at 4 months of age in February 1960. Approximately 1800 weaners had to be completely hand fed, mulga was lopped for adult sheep, and many non-experimental sheep were unloaded. Under these conditions general mating in 1960 was abandoned and joinings were made in a new experiment only, in which five rams were mated at "Gilruth Plains" and their half-sibs at Armidale. Selection for high wool weight will be carried out in each environment.

The current drought is so severe that the red soil areas of the mulga (*Acacia aneura*)–box (*Eucalyptus populifolia*) association are almost bare of grass and herbage, while in the brown and grey clay plains normally dominated by Mitchell grass (*Astrebla* spp.) the remaining plants are being greatly reduced.

Several of the major investigations at "Gilruth Plains" have been reviewed in the work on the animal breeding given in Section 3 of this chapter. Other studies at "Gilruth Plains" relate to the following.

(i) *Hornedness in Sheep*

The hypothesis reported last year on the inheritance of long scurs and aberrant horns in *Pp* Merino rams has been modified. It is now considered that there is a second series of alleles, S, S^1, and s, which result in the appearance of aberrant horns, long scurs, and short scurs respectively. It has been confirmed that the Dorset Horn breed is homozygous for either P', the gene initiating horn growth in Merino ewes, or for a gene closely linked with P'. A dominant gene producing polledness in the Border Leicester has been shown to be either P or a gene closely linked with *P*. Analysis has continued of data relating to the wool production of horned and hornless sheep. No differences have been found between polled and horned sheep.

(ii) *Efficiency of Conversion of Food to Wool*

A single-pen feeding experiment has been completed in which the aim was to study the rankings of the same sheep on different rations in relation to their individual efficiencies of conversion of food to wool. Interaction between sheep and ration was such that the rankings in gross efficiency changed little from one ration to the other.

In a second experiment selection for high clean wool weight per head under grazing conditions also resulted in the selection of more efficient animals.

8

Division of Animal Health

1. General

The Division of Animal Health is one of the three Divisions of the C.S.I.R.O. Animal Research Laboratories. It comprises the Animal Health Research Laboratory at Melbourne, the McMaster Animal Health Laboratory at Sydney, and the Veterinary Parasitology Laboratory, Brisbane, together with their associated field stations at Werribee and Tooradin in Victoria, at Badgery's Creek in New South Wales, and at Amberley in Queensland.

With the increase of livestock numbers in Australia and the higher stocking rates on improved pastures achieved as the result of scientific advances, diseases of livestock, whether of an infectious or non-infectious nature, continue to increase. Previous C.S.I.R.O. work in the field of animal health enables serious killing diseases, such as black disease of sheep, to be kept under adequate control, but new disease entities which cause considerable economic losses have arisen and require investigation. Research on problems such as the tick-borne infections in cattle, cattle pleuropneumonia, and diseases caused by internal parasites must be continued and expanded, and provision must be made for the development of studies on new problems such as those of newly reported virus diseases of cattle and pigs.

Dr. T. S. Gregory, formerly an Assistant Chief of the Division of Animal Health and Production, was appointed Chief of the Division of Animal Health with Dr. D. F. Stewart as Associate Chief. Dr. A. W. Turner agreed to hold the office of Assistant Chief until his retirement in August 1960. Dr. Gregory and Dr. Stewart continue to act as Officers-in-Charge of the Melbourne and Sydney laboratories respectively and Dr. F. H. S. Roberts as Officer-in-Charge of the Brisbane laboratory. Mr. A. J. Vasey, formerly Secretary of the Division of Animal Health and Production, has become Secretary of the Division of Animal Health.

The appointment of the Chief, Division of Animal Health, as Convenor and Chairman of the Sub-committee for the Control and Eradication of Contagious Bovine Pleuropneumonia in Australia, has recently been approved by the Agricultural Council. He continues to act as Convenor of the Technical Sub-committee on Infertility in Dairy Herds which has been set up by the Standing Committee on

Agriculture, and he acted as Chairman of the 1959 meeting. With Dr. A. W. Turner, Assistant Chief, he attended the meeting of the F.A.O. Expert Panel on Contagious Bovine Pleuropneumonia held in Melbourne in March 1960, and was elected Chairman.

Five Officers of the Division assisted universities by giving lectures in their special fields. The work of the Division of Biochemistry and General Nutrition on nutritional problems of the ruminant animal is reported in Chapter 10. The Division of Entomology undertakes research on the sheep blowfly and cattle tick (*see* Chapter 11).

(*a*) *Animal Health Research Laboratory, Melbourne*

Mr. J. R. Hudson, formerly of the Weybridge Laboratory of the Ministry of Agriculture (U.K.) and of the Division of Animal Health and Production of F.A.O., has been appointed as a senior member of the research staff to succeed Dr. A. W. Turner, whose retirement is imminent.

Dr. E. L. French visited the United Kingdom to attend, as Australian nominee, a specialist school for selected veterinary virologists held at the Infectious Diseases (Virus) Research Laboratory, Pirbright, by arrangement with the British Council. He also visited leading veterinary virology laboratories in the U.S.A., Europe, and Africa.

Both infectious and non-infectious diseases of ruminants are under investigation at this Laboratory. The infectious diseases include pleuropneumonia of cattle, those causing infertility in cattle, and virus diseases of cattle, sheep, and pigs. The non-infectious diseases are those associated with derangements of copper metabolism in sheep, including those primarily due to the hepatotoxic effects of the noxious weed *Heliotropium europaeum*. Extensive basic studies relating to all these conditions are being pursued.

The work on virus diseases is particularly exacting because it requires the attendance of research and animal attendant staff on all days of the week. Like many of the other major projects it is expensive because cattle and sheep constitute most of the animals used experimentally. Special facilities and additional outside staff for this work are not yet available, but good progress is being made under difficult conditions.

It was evident from the discussions at the Meeting of the F.A.O. Expert Panel on Contagious Bovine Pleuropneumonia that the contribution being made by this Laboratory to world knowledge of this disease is greater than that of any single laboratory elsewhere.

(*b*) *McMaster Animal Health Laboratory, Sydney*

Dr. D. F. Stewart, Officer-in-Charge, spent 6 months abroad visiting research establishments in New Zealand, the U.S.A., and Europe. He was invited to lead seminars at Cornell University, Johns Hopkins University, and the Rockefeller Institute, and he attended the XVIth International Veterinary Congress at Madrid as an Australian delegate.

Dr. W. Mulligan, of the Biochemistry Department of the University of Glasgow Veterinary School, spent some 10 months at the Laboratory as the Ian McMaster Fellow. Dr. C. H. Gallagher spent 4 months visiting laboratories in the United Kingdom and Europe, including the Carlsberg Laboratory at Copenhagen. Mr. R. I. Sommerville proceeded to the National Institute of Health, Bethesda, U.S.A., to spend a year working as an overseas post-graduate student with Dr. Weinstein.

Accommodation was provided for three F.A.O. Fellows and two Colombo Plan Fellows. In addition, a short course was given to the Indian Sheep and Wool Officers' Group who were visiting Australia under the Colombo Plan. Dr. R. K. Reinecke of the Onderstepoort Veterinary Research Institute spent several months at the laboratory under the terms of a South African Wool Board Bursary.

The major work of the laboratory includes the investigation of livestock diseases due to internal and external metazoan parasites, especially those due to helminth infestations, and of two infectious diseases of sheep, namely, footrot and mycotic dermatitis. Extensive basic studies support these investigations, especially those concerned with resistance to helminth infestations. Enzymological studies relating to the toxicity of pyrrolizidine alkaloids and of carbon tetrachloride, and to pregnancy toxaemia of sheep, also constitute an important part of the research program.

At the McMaster Field Station, Badgery's Creek, the Parasitology Block has been further developed and made more useful by the provision of extra water supplies and irrigation for improved pastures.

(*c*) *Veterinary Parasitology Laboratory, Brisbane*

In view of the requirement for planning future expansion of the research program, Dr. F. H. S. Roberts, Officer-in-Charge, has successfully negotiated with the Government of Queensland a leasehold grant of a site for a new laboratory at Indooroopilly. This is essential for expansion, as the present site at Yeerongpilly is already completely occupied. It is expected that a plan for building on the new site, and for a gradual transfer from the old site, will proceed over the next few years.

Dr. R. F. Riek was awarded a S.E.A.T.O. Research Fellowship and spent 3 months at the Veterinary Research Laboratory, Onderstepoort, South Africa. Mr. K. C. Bremner was granted a C.S.I.R.O. Overseas Studentship and left to pursue his studies at the Department of Veterinary Pathology of the University of Cambridge.

The laboratory continues to devote the major part of its research program to investigations on the internal parasites and the tick-borne protozoan infections of cattle. Other problems of importance to the livestock industry are studied as staff and facilities permit. Accommodation and facilities are provided for officers of the Division of Entomology engaged on field and laboratory research on the ecology and control of the cattle tick *Boophilus microplus*. For all this work the facilities available at the Amberley Field Station are being developed and fully utilized.

During the year training was given to two F.A.O. Fellows, one from Burma and one from the Federated Malay States.

2. Infectious Diseases of Livestock

(*a*) *Microbial Metabolism and Immunochemistry*

(1) *Pleuropneumonia of Cattle.*—This work is undertaken at the Animal Health Laboratory, Melbourne. Further work under this heading is recorded in Section 2(*d*)(i) of this chapter. In investigations of the causal organism (*Mycoplasma mycoides*), the function of glycerol, cholesterol, and fatty acids, both saturated and unsaturated, was studied. In the absence of any one of these, characteristic morphological changes accompanied by early lysis and death ("unbalanced growth") occurred unless growth was inhibited. The evidence strongly suggests that each of these nutrients is needed to maintain the integrity of the cell. These findings may have an important bearing upon viability of liquid vaccines. Studies with radioactive glycerol (DL-glycerol-1-^{14}C) showed that part is utilized to form a polyglycerophosphatide cardiolipin-like substance.

Further progress has been made in examining the galactan fraction. The hexose units may be the main determinants of specificity in serological tests for the diagnosis of the disease. The irreducible lipid moiety (approximately 4%) appears covalently linked with the carbohydrate.

(2) *Mycotic Dermatitis of Sheep.*—This work is undertaken at the McMaster Laboratory, Sydney. Further research under this heading is described in Section 2(*d*)(ii) of this chapter. A method has been developed for the production of large pure yields of the motile coccal phase of the causal organism, *Dermatophilus dermatonomus*, for physiological investigations. Quantitative cellular studies have indicated a structural basis for the behaviour of the cocci described previously. Their protoplasm is evidently divided into submicroscopic compartments in contrast with what is known of other bacteria.

(3) *Footrot in Sheep.*—This research is undertaken at the McMaster Laboratory, Sydney. Further work under this heading is described in Section 2(*d*)(ii) of this chapter. A broth medium has been developed for the cultivation of the causal organism, *Fusiformis nodosus*. The basic components, autolysed pancreas, a tryptic digest of casein, and a protein hydrolysate, are being characterized. A detailed study of the extracellular enzymes of *F. nodosus* has been made with particular reference to proteases hydrolysing keratin, prekeratin, and chemically modified keratin. Two peaks of protease production occurred during growth. The one formed early in growth during digestion of keratin and other proteins was too unstable for extensive study. The protease formed at the end of growth has been partially purified and characterized. Cysteine is essential for the digestion of keratin which proceeds at two pH optima, near neutrality, and at high alkalinity. The organism does not produce hyaluronidase, chondroitinase, collagenase, or phospholipase.

(*b*) *Virus Diseases of Livestock*

This research is undertaken at the Animal Health Laboratory, Melbourne. Further work in this field is described in Section 2(*e*) of this chapter. Increasing use is being made of the technique of tissue culture. With bovine foetal kidney cells, 20% ox serum in Medium 199 gave good growth and two cell lines were taken through eight subcultures. Substitution of lamb serum for ox serum resulted in failure of the cells to subculture in most instances. Bovine foetal lung cells, on the other hand, failed to adhere to the glass unless lamb serum was included in the 199 medium. Use of 20% lamb serum in Medium 199 enabled cells from eight different foetuses to be cultivated and, in one instance, 11 subcultures were successfully attained. Substitution of Hank's balanced salt solution with lactalbumin and yeast extract for Medium 199 resulted, with both lung and kidney cells, in complete coverage of the glass, and this was attained sooner than with Medium 199. With bovine foetal tissue cultures, it seems easier to carry out subcultures using Hank's solution in place of Medium 199.

Tissue cultures from weaner animals have also been prepared. A satisfactory routine has been established whereby tissue can be aseptically collected at a slaughter-house near the laboratory, to make each week bovine kidney, testis, and thymus tissue cultures and swine kidney cultures. At present these are all prepared as tube cultures, but it is planned to make use of monolayers in bottles and Petri dishes with an agar overlayer for the study of plaque formation by the viruses mentioned below.

(*c*) *Protozoan Diseases of Livestock*

The work described in this section of the Review is undertaken at the Veterinary Parasitology Laboratory, Brisbane. Further research under this heading is described in Section 2(*f*) of this chapter.

(1) *Serological Diagnosis of Tick-borne Infections in Cattle*.—In experimental infections of susceptible cattle a modified complement fixation test has led to greater accuracy in diagnosis and it has been possible to differentiate between antibodies to *Babesia bigemina* and *B. argentina*. Sera from cattle infected with *Gonderia mutans* or *Eperythrozoon wenyoni* gave no cross reaction with either of the babesia antigens, nor did a serum sample from a single animal infected with *Anaplasma marginale*. In experimentally produced babesiosis specific antibodies became detectable when the parasitaemia were subsiding and they persisted for at least 7 months. From the time when antibodies were no longer detectable the presence of the protozoan parasites may be demonstrable by subinoculation of blood for a period of up to 3 months.

(2) *Life-cycle of* Babesia bigemina.—By using a highly susceptible strain of the tick vector *Boophilus microplus*, progress has been made in studying the natural history of *Babesia bigemina*. By examining squash preparations the development of the protozoan parasite has been followed within certain cellular elements in the adult female, the egg, the larva, and the nymph. The examination of sections of fixed material is expected to reveal almost completely the life-cycle within the tick. It has already been found that transmission to the vertebrate host occurs

mainly during the nymphal stage 8-10 days after the attachment of the larvae, although there is occasional transmission at the other stages, probably when development within the larva is accelerated or that within the adult is retarded.

(*d*) *Bacterial Diseases of Livestock*

(i) *Cattle Diseases*

(1) *Pleuropneumonia of Cattle*.—Research on this disease has continued at the Animal Health Laboratory, Melbourne (*see* also Section 2(*a*)(1) of this chapter).

In the field of preventive inoculation research has largely centred upon the relative merits of "egg vaccine" and of standard "liquid vaccine", both prepared from the "V5" strain of *M. mycoides*. Whereas satisfactory viability of "liquid vaccine" was not always maintained after storage at 4°C for 2 months, "egg vaccine" remained satisfactory for at least 480 days. The need for care after its reconstitution at high environmental temperatures became apparent, for, although viability was good during 8 hr at 37°C, and indeed increased ten-fold, it fell catastrophically at 45°C (114°F), as did that of "liquid vaccine". Immunizing potency was compared by holding tail-tip inoculated (7 days earlier) and uninoculated ("control") cattle for 3–4 months in close confinement with a high proportion of infective cases. Local tail reactions were not alarming. Of 35 controls, 13 acquired pleuropneumonia, 6 died, and of 7 that recovered 3 were moderately severe cases; whereas of 35 "egg vaccine" (fifth passage) and 35 "liquid vaccine" animals only one of each group showed any signs, and they were mild. The pathological findings after necropsy, quantitized by means of an arbitrary scoring system, revealed mean score 3.7 ± 0.32 (S.E.M.) for controls, 0.77 ± 0.23 for the "liquid vaccine" group (i.e. 80% reduction), and 0.11 ± 0.01 for the "egg vaccine" group (i.e. 97% reduction). This confirmed the efficiency of standard "liquid vaccine" but demonstrated that "egg vaccine" was even more efficient. However, the high hopes that it might profitably replace "liquid vaccine" were dashed by results of an experiment designed to test its safety under extreme conditions. Following the inoculation of 78 adult dairy cattle, 24 underwent very severe tail reacations, in 8 definite pleuropneumonia lesions were found in the lungs, in 4 lesions were suspicious, and in 3 *M. mycoides* was recovered from bronchi. The emphasis therefore has meanwhile returned to "liquid vaccine". Standard broth culture vaccine sufficient to inoculate 1,300,000 animals was issued during the year.

In research on diagnosis the value of the interfacial precipitin test in the rapid diagnosis of lesions was shown, positive findings being recorded with putrified material (2–3 weeks old) and with formalin-preserved material (7 years). This test also demonstrated that suppression of agglutination tests, and more rarely the complement fixation test, observed in gravely ill animals, is associated with excess antigen in the blood. Examination of data accumulated over 8 years demonstrated the value of the slide agglutination blood test for rapid diagnosis of acute and recent pleuropneumonia, and for establishing a herd diagnosis, but revealed its limitations with chronic sequestrated cases. The basis of the bactericidal properties of immune sera was studied, and its dependence upon both a thermolabile and a thermostable component was shown.

Antigen for the complement fixation test was supplied gratis to testing authorities in Australia sufficient to test 19,800 cattle and gifts were made to Kenya (6600 tests) and the Philippines (3300 tests), in the first instance to assist with disease control and in the second for testing of animals imported from Australia.

(2) *Infertility in Cattle* (*Animal Health Laboratory, Melbourne*).—The epidemiology of experimentally induced vibriosis was studied in 106 dairy heifers mated in four groups and for only one oestrus period with infected bulls. Of the 106 heifers 57% developed evidence of infection and the conception rate overall was only 46%. In heifers that became infected the conception rate was 21% whereas in those that escaped infection it was 67%. It was evident that the outcome of one mating of an infected bull with one heifer does not always reveal his infection. With the four bulls used, three infected all of the first six heifers they served but the fourth failed to infect the second and fourth heifers served.

Other work showed that there are irregularities of infection when a heifer is mated once with an infected bull or receives on one occasion intravaginally his preputial washings or an electro-ejaculate.

Further work on the vaginal mucus aggulutination (VMA) test confirmed its usefulness as a means of establishing a herd diagnosis. The antigens of *Vibrio fetus* are being examined and preliminary immunological studies relating to possible vaccination procedures have commenced.

(ii) *Sheep Diseases* (*McMaster Laboratory, Sydney*)

(1) *Mycotic Dermatitis*.—(*See* also Section 2(*a*)(2) of this chapter). The host-parasite relationship has been more fully elucidated, particularly with respect to the germination of the motile coccus, the growth and fruiting of the mycelium in the lesion, and the release of the resultant crop of motile cocci. Motile cocci can escape into water on the surface of a scab during a brief period of about 1 or 2 weeks. At the end of this time the supply is exhausted and the surface of the scab has apparently ceased to be a source of infection.

The sebum film appears to provide a complete mechanical barrier to infection in Merino sheep. Scoring and cutting of the skin in shearing produce flaws in the film, and field observations indicated that cases with body infection were produced in this way. Restoration of sebacious protection takes from 1 to 2 weeks. The degree of the skin reaction to the invading hyphae is related to the age of the individual sheep and to its skin temperature. An acute reaction favours persistent infection.

Primary infections have been seen in lambs prior to marking. On two occasions lambs which appeared to be free of infection at an earlier age become infected when 2-3 months old. Dipping of infected flocks raised the incidence of the disease slightly. Lesions of mycotic dermatitis have been found on areas of the body affected by fleece-rot. The disease does not appear to be transmitted directly by contact from ewes to their lambs but it is possible that ewes act as a source of contamination.

(2) *Footrot and "Scald".*—(*See* also Section 2(*a*)(3) of this chapter.) Attempts to transmit footrot quickly and regularly on irrigated pastures failed. Although a lush growth was obtained by irrigation, the aerial portion of the plants dried out quickly when watering was discontinued. Attempts to transmit footrot under field conditions by infecting sheep with *Strongyloides papillosus* larvae also failed, although a severe reaction was produced interdigitally by the worms.

Further cases of "scald", which simulates early footrot, have been seen in the field. The lesions have been found during very dry periods. On individual sheep the lesion appears to be very transient at times. On one occasion "scald" was associated with a very severe outbreak of foot abscess.

(3) *Foot Abscess.*—A field experiment is being conducted to test whether a commercial *Fusiformis necrophorus* vaccine has any prophylactic value.

(*e*) *Virus Diseases of Livestock*

This work is carried out at the Animal Health Laboratory, Melbourne. (*See* also Section 2(*b*) of this chapter.)

(i) *Cattle Diseases*

Virus diarrhoea (winter diarrhoea) of cattle occurred in an epizootic form throughout Australia in 1958 when this virological work had just commenced. Preliminary attempts to reproduce the disease appeared to be successful, but no virus was isolated. In 1959 and 1960 only a few isolated cases have been reported. From three small outbreaks in Victoria in 1960, samples of blood and faeces were collected for inoculation into mice of various ages, into chick embryos via the yolk sac, and into tissue cultures of bovine kidney cells. The tests have all proved negative to date, but work is still in progress.

Necropsies were made in four suspected cases of bovine malignant catarrh. Prior to slaughter one of these animals was held at the laboratory for 8 days. Tranmission to healthy calves was attempted by inoculation into a prescapular lymph gland of a mixture consisting of buffy coat cells, lymph nodes, spleen, liver, and kidney. One calf showed after 68 days a rise in temperature and a fall in the white cell count. These and other tests failed to established a definite diagnosis, but stored material has been retained for later use.

Cases of rhinitis are being investigated to determine whether viruses play an aetiological role. From a herd with a history suggesting the presence of "nasal granuloma", nasal swabs were collected from four cows and inoculated into bovine foetal tissue cultures. No changes in these were subsequently observed.

In some overseas countries the virus disease of infectious bovine rhinotracheitis causes serious economic losses. From four herds in Victoria with suggestive signs of this disease several types of material were collected and inoculated into bovine foetal tissue cultures, but without observable effects.

Two herds of Hereford cattle have been under observation for about 2 years in a study of stomatitis. In these, 6–15-month-old animals have shown signs of this disease and also lesions of the muzzle and feet. The affected animals wasted and generally died. As a bacterial agent could not be detected a causal virus has been sought. In attempts at transmission by suitable material, young calves developed a mild disease characterized by a temperature rise, scouring, and a fall in white blood cells. No muzzle or foot lesions were detected. In another herd a similar disease affecting young cattle is being investigated. There has been some evidence that a virus disease capable of being transmitted experimentally is operative. Attempts are being made to isolate the agent by the application of current techniques.

(ii) *Pig Diseases*

(1) *Gastro-enteritis*.—Through the Victorian Department of Agriculture and the Melbourne University Veterinary Research Institute, material, from outbreaks in 7–9-week-old pigs of a disease characterized by gastro-enteritis and some incoordination and paralysis, has been submitted for examination. From two necropsy specimens an agent producing cytopathogenic effects in pig kidney tissue cultures has been obtained. In transmission experiments a mild transient scouring was produced and the agent was recoverable from faeces. The work is not completed.

(2) *Rhinitis*.—Through the Melbourne University Veterinary Research Institute tissues from pigs affected by a mild form of rhinitis have been obtained. Inoculation into tissue cultures of bovine kidney and swine kidney cells failed to reveal a cytopathogenic agent.

(iii) *Sheep Diseases*

Overseas workers have reported cases of pneumonia due to viruses. The situation in Australian sheep is being examined. From some specimens an agent producing a cytopathogenic effect in bovine kidney cell tissue cultures has been isolated. Its pathogenicity for sheep will be investigated.

(*f*) *Protozoan Diseases of Livestock*

Tick-borne Infections of Cattle (*Veterinary Parasitology Laboratory, Brisbane*)

(*See* also Section 2(*c*) of this chapter.) Epidemiological investigations were made on cattle in south-eastern Queensland where areas vary in regard to the degree and continuity of tick (*Boophilus microplus*) infestation of herds. Rates of infection with *Babesia* spp. (*B. bigemina* and *B. argentina*) were determined on the basis of examination of stained thick blood smears with the following results.

(1) In a permanently tick-infested area during May–September 1959, the overall combined infection rate was steady at about 30%. In animals younger than one month it was 10% and due entirely to *B. bigemina*. At age 1–6 months

the combined rate was 60% and *B. bigemina* was responsible for 80% of the infections. At age 6–12 months the combined rate was again 60% but the differential rates for *B. bigemina* and *B. argentina* were about equal. At age 1–2 years the combined infection rate was 70% and *B. argentina* constituted about 70% of the infections. In cattle older than 2 years *B. argentina* caused 90% of the infection and the combined infection rate decreased with age until it had fallen to 10% in the oldest animals.

(2) In an area marginal for tick infestation the combined infection rate was 30% during the winter, whereas in the spring when ticks had almost disappeared it was 16%. The highest combined infection rate of 50% was found in cattle 6–12 months old and the differential infection rates varied in relation to age in a manner similar to that described for the permanently tick-infected area.

3. Non-Infectious Diseases of Livestock

(*a*) *Chemical and Experimental Pathology, Toxicology, and Pharmacology*

(i) *Poison Plant Investigations — Pyrrolizidine Alkaloids*

(*See* also Section 3(*b*) of this chapter.) Earlier work showed that one cause of the sheep disease, "toxaemic jaundice", was grazing the plant *Heliotropium europaeum.* It was found that this plant contains a number of pyrrolizidine alkaloids, and these have been isolated in pure form by officers of the Chemical Research Laboratories (*see* Chapter 34, Section 7).

(1) *Studies on Rats* in Vivo (*Animal Health Laboratory, Melbourne*).—The disease produced in rats by repeated injection of the pure alkaloids is similar to the natural disease in sheep and intensive studies in the rat have been directed towards elucidating the disease processes. In both species these alkaloids set up a progressive chronic disease of the liver which is characterized by enlargement of parenchyma cells and their nuclei (megalocytosis), and this lesion has been constantly found in heliotrope poisoning of sheep.

In an experiment to determine whether a non-lethal course of injections of the alkaloid, heliotrine, increased the susceptibility to a further course instituted after varying rest periods, an initial course of 2.1 LD_{50} in three-times weekly injections was given. After rest periods of 10, 15, 20, 25, and 30 weeks subgroups were started on further injection courses at the same dose rate as before and continued until death. The total dose required to kill rats in these subgroups was compared with that required to kill rats which had not had the preliminary course. In this way it was possible to demonstrate that the liver was affected by the first series of injections in such a way that a lethal effect was subsequently produced by smaller doses than were required to kill normal rats. This effect persisted throughout the rest period even when this was as long as 30 weeks. However, the total amount of alkaloid required to produce this lethal effect was the same whether it was given all in one continuous course of three-times weekly injections or in two courses separated by rest periods of 10–30 weeks.

The *N*-oxides of the alkaloids have a much lower acute toxicity than the bases, and consequently larger doses can be given at a single injection without producing liver necrosis. Therefore, lasiocarpine *N*-oxide was used to determine whether the liver-cell enlargement was a progressive process and the cause of the lethal effects, by giving comparatively large doses at infrequent intervals. When one, two, four, or eight doses were given at three-weekly intervals to groups of rats it was found that the single dose just as effectively produced liver-cell enlargement as the repeated doses, but unlike the latter it did not shorten the survival time as compared with control rats. Enlargement of the parenchyma cells appears to be only a preliminary to subsequent pathological processes that cause death.

Sheep which die in the field from heliotrope poisoning always have abnormally high levels of copper in the liver. So also do rats given repeated injections of the pure alkaloids. Intensive study in the rat, however, has shown that copper does not start to accumulate until the liver lesion is fairly well advanced, but it then accumulates rapidly. In one experiment it was found that 0.1 LD_{50} of heliotrine could be given three times weekly for a period of 2 months without materially altering the copper status of the rats. If injections then ceased the liver copper concentration rose to four to five times normal during the next 2 months and then slowly returned to normal. This suggests that the effect of the alkaloid on the metabolism of the liver cell (rather than any combination between the alkaloid and copper) may be responsible for the copper accumulation in the liver.

With the methods developed for the determination of minute amounts of the alkaloids in animal tissues it has been shown that the maximum concentration of alkaloid in the liver is reached 3–5 min after intraperitoneal injection and then disappears rapidly. Among pathways by which the alkaloid may be metabolized in the liver it has been found that one is hydrolysis to heliotridine. Heliotridine and the original alkaloid may be oxidized to the *N*-oxide and the esterifying acid may be demethylated.

Studies on the blood chemistry of rats during chronic intoxication with heliotrine have indicated an early fall in blood albumin and an increase in serum transaminases. Blood clotting becomes impaired owing to a deficiency in prothrombin and in factor VII. As the disease process progresses these abnormalities increase in degree and in the last stages ammonia levels rise steeply.

An experiment dealing with liver regeneration after partial hepatectomy in rats treated with pyrrolizidine alkaloids has been completed. In the liver damaged by a single injection of lasiocarpine *N*-oxide the pattern of mitotic activity was greatly changed but regeneration was not inhibited. With multiple doses liver damage may be so severe as to greatly damage regenerative capacity.

(2) *Studies on Rat Tissues* in Vitro.—At the McMaster Laboratory, Sydney, it was found that all pyrrolizidine alkaloids tested increased permeability of mitochondrial membranes, and thus caused the loss of pyridine nucleotides. In this way the alkaloids inactivate mitochondrial enzyme systems which require pyridine nucleotides for electron transfer, and stimulate the succinoxidase system.

The effect of the pyrrolizidine alkaloids is associated with the cyclic base, and in particular with the ring nitrogen; heliotridine is as effective in altering mitochondrial metabolism as is heliotrine, and the *N*-oxides of the alkaloids have no effect. It was also shown that the alkaloids of *Heliotropium europaeum* and their free α-hydroxy acids are capable of forming complexes with copper.

In pharmacological studies the effect of neuromuscular blocking agents on mitochondria was investigated. D-Tubocurarine and a series of inorganic metal complexes (all known neuromuscular inhibitors) were found to have a similar action on mitochondrial enzyme systems as the pyrrolizidine alkaloids, which are also neuromuscular inhibitors. They all increase mitochondrial permeability under oxidizing conditions and lead to the inactivation of pyridine nucleotide–dependent enzyme systems. D-Tubocurarine is taken up by mitochondria under oxidizing conditions. Both increased mitochondrial permeability and uptake of D-tubocurarine seem to be dependent upon the reoxidation of reduced diphosphopyridine nucleotide, as these effects are inhibited by sodium amytal. All the complex ions tested carried two positive charges, but varied in their charge distribution. Their effect on mitochondrial metabolism varied in accordance with their charge distribution. Those complexes which caused inhibition of pyridine nucleotide–dependent oxidations at higher concentrations showed an uncoupling effect at lower concentrations.

At the Animal Health Laboratory, Melbourne, the isolated rat's phrenic nerve–diaphragm preparation has been applied to an examination of the activity of the pyrrolizidine alkaloids in blocking neuromuscular transmission. However, the prolonged recovery periods of the preparation following each test have limited its application. This has been shown to be due to slow elution of the alkaloids from the tissue. It was found that the unesterified base of the major heliotrope alkaloids, heliotridine, and the *N*-oxides, is much less potent than the bases. The blocking activity of the alkaloids is largely curare-like in nature. Cross potentiation of the nerve-muscle preparation between curare or curare-like drugs and the pyrrolizidine alkaloids has been demonstrated.

(ii) *Copper Metabolism*

(*See* also Section 3(*b*) of this chapter.)

(1) *In Sheep*.—At the Animal Health Laboratory, Melbourne, several studies have been commenced to gain a fuller understanding of this subject. A group of ewes was depleted of copper by providing an additive of 12–15 mg of molybdenum and 5 g sulphate daily to their diet during 1958. Those with liver copper values between 10 and 20 p.p.m. and blood copper values below 0.4 μg/ml were mated in January 1959. The remainder were mated in July 1959 when their copper status had been similarly reduced. None of the lambs showed clinical evidence of ataxia nor was any evidence of demyelination of the central nervous system found at necropsy. Liver copper values in these lambs ranged from 5 to 20 p.p.m. and blood copper levels as low as 0.04 μg/ml were recorded. None of the ewes has shown

any evidence of fleece lesions, even though many of them have maintained blood-copper levels of 0.2 μg/ml or less for a period of 8–12 months. The reasons for the differences between the apparent health of the artificially depleted sheep and copper deficiency under field conditions are being investigated.

It has been shown that molybdenum intakes of as little as 2–5 mg/day can seriously limit the storage of copper when copper intake is low and sulphate high. Studies on copper distribution between red cells and plasma in the blood of sheep during a haemolytic crisis have shown that there is a steady transfer of copper to the red cells in the 24 hr preceding haemolysis. This results in a much higher concentration of copper on the red cells than earlier measurements of whole blood copper would indicate and probably accounts for their breakdown.

In Western Australia, in cooperation with the Department of Agriculture, an experiment was planned at Merridin on the relative rate of loss of copper after administration to sheep by either the oral or the intravenous route. No group difference was found although large differences were found in individual sheep of either group. After either method of introduction copper appears to be stored in the liver in the same form.

(2) *In Fowl, Duck, and Rabbit* (*In cooperation with the Western Australian Department of Agriculture*).—The results of experiments with the fowl and duck await statistical examination. Although copper was in a form allowing rapid excretion, sites of copper deposition in the liver could not be detected in histological sections subjected to staining with rubeanic acid. On the special diets provided, age appeared to have little influence on the accumulation of copper in the liver of the cockerel, and by contrast with the duck there was little change in the concentration of liver copper from birth to 19 weeks of age. In both, total copper content of the liver increased with age.

Some experiments with rabbits are being made for comparative purposes using the rabbit as a type of non-ruminant mammal.

(iii) *Clover Oestrogen* (*In cooperation with the Western Australian Department of Agriculture*)

Work on the isolation of the oestrogen in saponified clover was largely held in abeyance. The oestrogen appears highly active at doses below 1 μg per mouse; no crystalline active compounds were obtained.

(*b*) *Field Observation on Non-infectious Diseases*

(i) *Sheep*

(1) *Chronic Copper Poisoning of Sheep* (*Hepatogenous*) (*Animal Health Laboratory, Melbourne*).—In Australia the disease of sheep which is most frequently accompanied by jaundice comes under this classification. Previous work has shown it to be primarily due to a specific type of liver damage (hence hepatogenous) which is produced when sufficient of the poisonous pyrrolizidine alkaloids is obtained by sheep, for example, by eating an excessive quantity of the

plant *Heliotropium europaeum*. A frequent sequel to such liver damage is the abnormal storage of copper in the liver of the affected sheep even though it takes a diet which is satisfactory for normal sheep. A further consequence of this excessive copper storage may be the breakdown or lysis of red blood cells followed by jaundice and usually by death. Until other scientists find means of controlling or eradicating this weed graziers must try to prevent sheep from eating it. In the current year seasonal conditions in Victoria and the Riverina have favoured its growth and consequent losses have resulted. Previous studies on pathological changes in the liver of affected sheep provided a means of confirming diagnosis and this is being used by diagnostic laboratories. Basic studies (*see* Section 3(*a*)(i) of this chapter) are of importance not only in relation to this disease of sheep but also to diseases of other livestock, for example, Kimberley disease of horses.

(2) *Chronic Copper Poisoning of Sheep* (*Phytogenous*) (*Animal Health Laboratory, Melbourne*).—Sometimes, whether the liver is normal or damaged, sheep on a particular pasture (hence phytogenous — of plant origin) may develop chronic copper poisoning. Occasionally this may be due to too much copper in the diet, but generally in Australia it is caused by a pasture with only usual amounts of copper but lacking other minerals in quantities that keep copper absorption and storage under proper control. These conditions may apply especially in a pasture mainly composed of subterranean clover growing rapidly after early autumn rains. Basic studies (*see* Section 3(*a*)(ii) of this chapter) are directed to a better understanding of the plant and animal factors governing the metabolism of ingested copper.

4. Diseases of Livestock Caused by Metazoan Parasites

(*a*) *Endoparasites*

(*See* also Section 4(*b*) of this chapter.)

(i) *Resistance and Immunity in Hosts Subjected to Infestations with Gastro-intestinal Worms*

(1) *Sheep, Rats, and Guinea Pigs as Host Animals* (*McMaster Laboratory, Sydney*).—This subject provided a major field for research. The parasite-host systems under investigation were *Haemonchus contortus* in sheep, *Trichostrongylus colubriformis* in the guinea pig and the sheep, and *Nippostrongylus muris* in the rat. Larvae of the infective stage were used in assessing the influence of X-rays on subsequent development and immunogenicity. For each system the requisite dose of irradiation for larvae to be used in immunity tests was estimated experimentally. With each system it was found that, as the X-ray dose was increased, so also was the proportion of females found in the population of adult worms that developed from the irradiated larvae. A comparison of rates of exsheathment of normal and irradiated *Haemonchus contortus* larvae was made. Doses of X-rays up to 100,000 r had no retarding effect on exsheathment.

An experiment was commenced to test the nature and degree of any immunity produced in lambs after receiving two doses of *H. contortus* larvae treated with an X-ray dose of 60,000 r. Larvae similarly treated (60,000 r) were about equally effective as untreated larvae in producing self-cure, and in sheep which received them and which underwent self-cure immunity is now being tested by a later challenge with normal larvae.

In a field trial 20 2-year-old ewes were given two doses of irradiated (60,000 r) *H. contortus* larvae at an interval of 20 days during a period when they were subject to natural infestation. When compared on the basis of faecal egg counts with a control group in the same environment the treated sheep appeared to have received no benefit.

Studies on acute haemonchosis produced by administration of large doses of normal larvae showed that within certain limits the greater the number of larvae given the greater will be the retardation in their development and the smaller will be the resulting worm burden in the host.

(2) *Cattle as Host Animals* (*Veterinary Parasitology Laboratory, Brisbane*).—(*See* also Section 4(*b*) of this chapter.) The parasite-host system studied was *Oesophagostomum radiatum* infestation of cattle. The effects of X-irradiation on the viability of larvae and on development in their final stages were observed. At 20,000 r no significant inhibition of development was seen. There must have been a highly selective lethal effect on larvae destined to be males because there was an unusually high proportion of females among the adults that were recovered. Calves given the irradiated (20,000 r) larvae as an oral vaccine were found to be as resistant to reinfestation with normal larvae as control animals which had first received the same dose of untreated larvae.

In other immunological studies it was found that in experimental calves rendered resistant to *Oe. radiatum* the mechanism of resistance was directed mainly against the fourth stage of reinfestation larvae when they had returned from the gut wall to the gut lumen and it caused them to be almost immediately eliminated. Evidence is being sought regarding the stage or stages of the parasite within the host responsible for the stimulation of resistance or immunity.

The serological responses were noted of calves subjected to experimental infestations. Complement fixing antibody could be found when resistance in the host was developing or established; this is in contrast with findings in natural infestations with a mixture of species which included *Oe. radiatum*. Experimental infestations as well as those naturally contracted continued to develop at a time when the titre of specific haemagglutinins was high. In colostrum samples complement fixing antibodies were always detected but haemagglutinins were sometimes not detected. The results of examination of faeces for the presence of antibodies were not conclusive.

(ii) *Anthelmintics*

(1) *Sheep* (*McMaster Laboratory, Sydney*).—Phenothiazine was subjected to further study. Chemical work on new syntheses of phenothiazine and its

derivatives was completed. Attempts are now being made to prepare a series of pentacyclic derivatives and to test them for physiological activity. A water-soluble derivative is at present being prepared for testing. The anthelmintic value of phenothiazine in different preparations or administered by different routes has been a subject for investigation. In sheep infested with *H. contortus* and *T. colubriformis* small doses of phenothiazine were injected into the rumen. Provided the sheep were not allowed to drink for 24 hr before and 24 hr after drug injection, egg production by the residual worms was prevented for a period of up to 30 days. Sheep maintained on a low protein diet became anaemic and sometimes died after receiving fine-particle–size phenothiazine as a drench. The absorption and excretion of phenothiazine of known particle size has been studied.

Several other drugs were tested for anthelmintic efficiency. 3-Chloro-4-methyl-7-oxycoumarine thiophosphate ("Asuntol", Bayer "21/199") when subjected to tests in the field was found to be effective against most of the gastro-intestinal nematodes but not against *Ostertagia* spp. In laboratory and field trials at a dose of 0.3–0.5 g/100 lb body weight it killed 10 of 50 sheep, and there was a very narrow margin between the toxic dose and the effective anthelmintic dose. 4-*tert*.-Butyl-2-chlorophenyl-methyl-methyl phosphoramidate (Dowco "132", "Ruelene", "Montrel") at 10 g/100 lb body weight was highly effective against *H. contortus* and *Trichostrongylus* spp. but was erratic in action against *Oesophagostomum* spp. and *Chabertia ovina*. Larger doses were fatal to some sheep. *O*,*O*-dimethyl-*O*-4-(methyl mercapto)-3-methylphenyl thiophosphate at a dose rate of 5 g/100 lb body weight killed *H. contortus* but was fatal to the sheep. *O*-(4-*tert*.-butyl-2-chlorophenyl)*O*-methyl methyl phosphoramidothioate at a dose rate of 12 g/100 lb body weight reduced egg production temporarily in some sheep but had no effect in others. 7-Oxy-3,4-tetramethylene coumarine *O*,*O*-diethyl thiophosphate was effective against *H. contortus* and *Trichostrongylus* spp. but not against *Oe. columbianum*, and there was very little margin between the effective and the toxic dose. Bephenium hydroxynaphthoate proved in the field to be more effective than the embonate against *Ostertagia* spp. and *Trichostrongylus* spp. Bephenium hydroxynaphthoate used at a dose rate of 10 g/100 lb body weight in the field was effective against *H. contortus* and *Oe. columbianum* but 20 g was required for effectiveness against *Trichostrongylus* spp. 1-Naphthyl-*N*-methyl carbamate ("Sevin") at a dose rate of 10 g/100 lb body weight was fatal to the host but had little effect on *H. contortus*. 3,4,4′-Trichlorocarbanilide at a dose rate of 20 g/100 lb body weight had fair anthelmintic activity against *Ostertagia* spp. and *C. ovina*, but not against *Oe. columbianum* or *Trichostrongylus* spp.

Carbon tetrachloride is efficient as an anthelmintic in liver fluke (*Fasciola hepatica*) infestation of sheep but shows unpredictable toxicity. In investigation of this toxic action, *in vivo* studies have shown that the precursors of pyridine nucleotides, nicotinic acid, and tryptophane, maintain high levels of pyridine nucleotide in both rats and sheep treated with carbon tetrachloride and protect against the toxic effects of carbon tetrachloride. *In vitro* studies show that the treatment of isolated mitochondria with carbon tetrachloride caused an "aging" effect which could be reversed by ethylenediaminetetra-acetic acid.

(2) *Cattle* (*Veterinary Parasitology Laboratory, Brisbane*).—Phenothiazine of fine-particle size at a dose rate of 2 g per 100 lb body weight was ineffective against 14-day-old *Cooperia pectinata* and *C. punctata* and only moderately effective against mature worms of these species.

Bephenium hydroxynapthoate at a dose rate of 15 g per 100 lb body weight was highly effective against mature *Cooperia* spp., *Haemonchus placei*, and *Oe. radiatum*, but not against *Bunostomum phlebotomum*. There was evidence of some activity against *Trichostrongylus axei*.

When calves infested with *Moniezia benedeni* were given daily oral doses of copper sulphate no significant change in the copper status of the parasites was found. When segments of worms were placed in a much higher concentration *in vitro* an increase in copper content could be demonstrated. It seems likely, therefore, that copper salts would exercise an anti-cestode activity in the gut only if they were in a concentration permitting action by free copper after some of the copper intake had been deviated by local physiological reactions.

(3) *Mice* (*Veterinary Parasitology Labortory, Brisbane*).—The mechanism of anthelmintic action of copper sulphate on cestodes was examined in mice infested with *Hymenolepis nana*. Repeated dosage with copper sulphate did not increase the copper content of the worms.

(iii) *Ecology*

(1) *Cattle Parasites* (*Veterinary Parasitology Laboratory, Brisbane*).—The ecology has been studied of the preparasitic stages of nematodes in the pasture. At Amberley Field Station larvae of *H. placei* cannot be recovered from pasture during mid to late winter. This is believed to be due to temperatures in the dung pat during the winter becoming too low for their development. In 1959 during the month of June temperatures below 50°F prevailed for 9 hr daily and rose above 60°F only for 7 hr daily. In July these periods were 16 and 6 hr respectively.

Preliminary observations on the value of breaking up and scattering dung pats in the pasture as a means of control showed that this procedure effectively shortened the "reservoir" period of the pat in the summer, but not in the winter.

Trials have been commenced to determine the efficiency of control by a rotational grazing system based on ecological data, relating to the pasture stages, obtained during the past 3 years. The system aims at using three pastures and moving the calves, during periods of larval abundance, into a pasture which has been spelled for at least 4 months. The need for anthelmintic treatment is considered between each rotation. In their early life animals are thus exposed only to low populations of larvae and should have become resistant by the time they are moved to their permanent pasture. Results to date have been promising but with *Oe. radiatum*, because of its histotropic phase, two treatments at rotations will be required.

Infective larvae of *Oe. radiatum* and *H. placei* were recovered from cultures at 102°F, but not at 105°F. Larvae of *Cooperia* spp. (*C. pectinata* and *C. punctata*) reached the infective stage at 105°F, but not at 110°F.

Studies continued on the incidence and distribution of the trematode *Fasciola hepatica*. Previous observations were confirmed on the decline of populations of the snail vector on the coastal plain near Brisbane during the summer.

(2) *Sheep Parasites* (*McMaster Laboratory, Sydney*).—Studies relating to the trematode *Fasciola hepatica* have been undertaken at the laboratory and in the field (*see* also Section 4(*a*)(iii)(1)).

All 16 named species of the limnaeid snails which can act as intermediate hosts for *F. hepatica* have been shown to be varying populations of a single species, *Limnaea launcestonensis* Tenison Woods, 1876. Snails obtained from several Australian States and from geographically different environments, and snails of various ages proved equally susceptible to *F. hepatica* infestation. Significant differences in viability were found in metacercariae developed under different environmental conditions. Temperature, nutrition, population density, and other environmental factors were found to greatly influence the multiplication and development time of *F. hepatica* larvae in the snail. Larvae reached the infective cercarcial stage in a period varying from 25 days to 150 days. High population densities exercised a depressing effect on the rate of reproduction and growth. Evidence obtained from the New South Wales central plains showed that during dry years snails are able to survive in a few foci from which rapid spread associated with serious infestations of liver fluke can occur during the occasional wet year.

A satisfactory method was developed for harvesting metacercariae. Mice, guinea pigs, and sheep have been artificially infested with them. The effects of exposure to X-irradiation on metacercariae are now being studied.

(iv) *Pathology of Gastro-intestinal Worm Infestations*

(1) *Cattle* (*Veterinary Parasitology Laboratory, Brisbane*).—Calves heavily infested with *Oe. radiatum* developed a normochromic oligocythaemia and a severe hypoproteinaemia. In an endeavour to find the causative factors nitrogen balance studies are being made on experimental calves. In moderate infestations whole blood copper levels were found to be depressed but no effect on plasma copper or corpuscular copper was evident. In calves which received irradiated larvae the degree of anaemia and hypoproteinaemia was considerably less.

(2) *Rats* (*McMaster Laboratory, Sydney*).—Studies continued with *Nippostrongylus muris* infestations in rats. It was found necessary to express rates of absorption in terms of the dry weight of mucosa if a fundamental comparison between normal and infested rats were to be made. By the use of isotopically labelled sodium chloride and water to measure unidirectional fluxes across the jejunum it was shown that the accumulation of fluid in the gut is fundamentally due to a derangement of absorption. There is also an increased influx because the weight of mucosa per unit length of gut is increased in the infested animal. Glucose absorption from the jejunum is reduced. The possibility of an increased rate of absorption from the lower ileum of infested rats has not been definitely established. The greater recovery of isotopically labelled protein from the gut of these rats is due to a considerably lower rate of digestion and to a slightly

lower rate of absorption. Gastric digestion and emptying rate are not affected. The uncoupling of oxidative phosphorylation in mitochondrial preparations of the infested jejunum is not due to any increase in the calcium concentration in intestinal tissue. The oxygen uptake of whole cell preparations of jejunal mucosa is being measured. Infested rats were found to be hypoglycaemic. Loss of appetite greatly influences loss of body weight in this infestation, as this loss can be closely simulated in controls by restriction of the food intake to that of the infested animals.

(v) *Growth of Nematode Worms* in Vitro (*McMaster Laboratory, Sydney*)

A study is being made of the parasitic stages of the rat parasite *N. muris* in conjunction with Dr. Paul P. Weinstein at the National Institute of Health, Bethesda, Md., U.S.A. At present, the minimum time required for the attainment of maturity *in vitro* is 14–21 days, compared with 5 days *in vivo*. In spite of this slow growth, cultured worms which have been transferred to rats at different stages of development have been able to attain maturity and produce segmenting eggs. Slow growth *in vitro* is not an overcrowding phenomenon; as few as 20 larvae will grow no faster than 500 in the same volume of medium. It has been found that if 100 infective larvae are cultured in a medium composed of chick embryo extract, serum, and a vitamin mixture, fourth stage larvae first appear at 7 days. The appearance of this stage is now being used as an index of the efficacy of the growth promoting properties of the medium. Concurrently, the survival and growth of late fourth stage larvae obtained from rats and incubated in a basal salt medium with the addition of human or rat serum is being studied. Worms will survive up to 7 days in this type of medium, which will be used as a base for the addition of potential growth promoting factors.

(*b*) *Endoparasitic Diseases of Livestock and their Treatment*

(i) *Anthelmintic Treatments*

(1) *Sheep* (*McMaster Laboratory, Sydney*).—(*See* also Section 4(*a*) (ii) of this chapter.) In the section of this work relating to nematodes, phenothiazine was subjected to several tests. Further work in laboratory and field trials confirmed the variation in efficiency between phenothiazine preparations from different sources. A phenothiazine product of high purity (over 95%) and a relatively coarse particle size (7000 sq. cm/g) was much less effective against *T. colubriformis* than one of a lesser degree of purity (85% phenothiazine) and of fine particle size (12,000 sq. cm/g). In two field trials phenothiazine was highly effective against *Ostertagia* spp., mature *Nematodirus* spp., and *Trichostrongylus* spp. A dose of 10 g for adult sheep was not highly effective in an outbreak of haemonchosis. In the same outbreak a dose of 2.5 g/100 lb body weight of *O*,*O*-dimethyl-1-hydroxy-2,2,2-trichloroethyl phosphonate ("Neguvon", Bayer "L13/59") was also ineffective. A suggestion by graziers that strains of worm parasites of sheep had become resistant to phenothiazine was not supported by an investigation which showed that persistence of unthriftiness after drenching could not be attributed to phenothiazine-resistant strains of worms. It was probably due to malnutrition.

Further observations on the seasonal changes in the gastro-intestinal worm burden of young sheep in east Gippsland (Victoria) showed that the number of worms increased from the autumn to reach a maximum infestation late in July.

At Oberon (N.S.W.) trials on fat lambs showed that worm burdens with *Ostertagia* spp., *Trichostrongylus* spp., and *Nematodirus* spp. increased from November when the lambs were 6 weeks old, reached highest levels toward the end of January, and then declined. Monthly drenching with either bephenium hydroxynaphthoate or phenothiazine reduced worm egg counts and the incidence of scouring. When the worm burdens were greatest the incidence of scouring was also greatest and weight gains decreased, but coccidiosis was a complicating factor. A high incidence of fly strike was a consequence of scouring and this contributed to reduced weight gains.

In the section of this work relating to trematodes (*see* also Section iv(*a*)(ii) above), "Freon 112", tetrachlorodifluoroethane, mixed with liquid, was found to be of low toxicity to sheep and highly effective against the mature form of the liver fluke *F. hepatica* when used at a dose rate of 0.15 g/lb body weight.

Hexachlorophane has exhibited a high degree of anthelmintic efficiency in preliminary tests with sheep infested with *F. hepatica*.

(2) *Cattle*.—(*See* also Section 4(*a*)(ii) above.) At the Veterinary Parasitology Laboratory, Brisbane, Bayer "L13/59" is being tested in the field as an anthelmintic against nematodes. While calves were undergoing monthly treatment at a dose rate of 2.5 g per 100 lb body weight they exhibited very low worm egg counts, and 9 months after the course of treatment started their average weight was 73 lb greater than that of untreated controls. A group receiving 0.75 g per 100 lb body weight monthly exhibited only slightly lower egg counts than controls, but after 9 months their average weight exceeded that of the controls by 40 lb. When calves were tested after the 9 month period it was found that the development of resistance to infestation had not been significantly affected by the course of treatment. No signs of toxic effects were seen following administration of the drug in these doses. When tested for toxicity at a dose rate of 5 g/100 lb body weight, local calves of poor to good bodily condition even after a second treatment within a week showed only transient signs of discomfort.

At the McMaster Laboratory, Sydney, current observations on the seasonal changes in worm burdens of cattle in the Bombala district of New South Wales had to be restricted on account of drought. The infestations remained extremely light.

(*c*) *Ectoparasites*

(i) *Parasites of Miscellaneous Hosts*

(1) *Tick Taxonomy* (*Veterinary Parasitology Laboratory, Brisbane*).—Revision of the species of the genus *Ixodes* has been completed and 15 known species and four new species have been recognized. The genus *Haemaphysalis* is now being studied. Taxonomic studies are also being made on

the ticks previously determined as *Amblyomma triguttatum,* which has recently been shown to be a possible vector of Q fever. Three species may be included in this complex.

(2) *Toxin of* Ixodes holocyclus (*McMaster Laboratory, Sydney*).—The pink cuticular excretion of *Ixodes holocyclus* has been tenatively classified as an iron-polyphenol pigment. Investigation of the intermediary metabolism of tick-infested mice revealed a disturbance in the functioning of pyridine nucleotides.

(ii) *Sheep Parasites* (*McMaster Laboratory, Sydney*)

(1) *Itch Mite,* Psorergates ovis.—(*See* also Section 4(*d*) below.) The details of the life-cycle of the itch mite of sheep, *Psorergates ovis,* have now been determined. There are six stages: the egg, the larva, three nymphal stages, and the adults, males and females. The cycle is completed on or beneath the stratum corneum in 4–5 weeks. There is no evidence that any stage is resistant to adverse environments. Mites have been successfully transferred to other sheep including a lamb 3 weeks of age. The only clinical symptom visible was a white scurf on the skin, which has been frequently observed in association with heavy infestations in the field.

(2) *Body Louse,* Dalaminia ovis.—(*See* also Section 4(*d*) below.) High humidities have been found to be lethal to the eggs of *Dalaminia ovis* only at the time of hatching, and it should now be possible to determine the influence of humidity on sheep louse populations in the field. Studies to determine whether there is a seasonal variation in the fertility of the eggs of *D. ovis* are in progress.

(iii) *Cattle Parasites* (*McMaster Laboratory, Sydney*)

Body Louse, Haematopinus eurysternus.—Investigations have shown that this is the main louse infesting cattle, but is of little economic importance. However, the irritation causes cattle to rub and damage fences. Initial trials indicated that a single spraying with 0.05% dieldrin in May should give satisfactory control.

(iv) *Horse Parasites* (*McMaster Laboratory, Sydney*)

High humidities have been found to be lethal to the eggs of the body louse, *Dalaminia equi.*

(*d*) *Livestock Infestations and their Treatment*

(i) *Sheep* (*McMaster Laboratory, Sydney*)

(1) *Body Lice.*—Arsenic solutions proved capable of eradicating infestations from sheep when used as sprays in concentrations of 0.225, 0.123, and 0.007% arsenic trioxide.

(2) *Itch Mite.* -Arsenic solutions when applied by tip-spraying to newly shorn sheep failed to effect control. "Sevin" in concentrations of 0.1 and 0.01% failed to give a total kill of mites when applied in patch tests.

9

Division of Animal Physiology

1. General

The new Division of Animal Physiology forms part of the C.S.I.R.O. Animal Research Laboratories, and comprises the Ian Clunies Ross Animal Research Laboratory at Prospect, N.S.W., the Regional Pastoral Laboratory at Armidale, N.S.W., and a research unit temporarily located at the University Farms, Camden, N.S.W.

The Division of Animal Physiology studies all those aspects of the healthy sheep's life and function which are likely to determine its productivity. This work is aimed to provide a sound scientific basis for improvements in animal husbandry. The Division does some research on beef cattle and it is proposed to expand this in the future.

The Division of Biochemistry and General Nutrition studies the nutritional processes of the ruminant animal (*see* Chapter 10).

(*a*) *Ian Clunies Ross Animal Research Laboratory*

This Laboratory, headquarters of the Division of Animal Physiology, has been named in memory of the former Chairman of C.S.I.R.O., the late Sir Ian Clunies Ross. The main building of the laboratory was occupied in 1959, and was officially opened on March 9, 1960, by the Right Honourable Lord Casey, P.C., C.H., D.S.O., M.C., M.A.

A special "Sheep Series of Liaison Notes" has been prepared for the use of extension officers in the State Departments of Agriculture. These have proved so useful that it is proposed to maintain this service as a permanent feature of the Laboratory's work.

The "Liaison Notes" have now covered the major aspects of reproduction, and this contribution has been further supported by a special refresher course held at the Laboratory. The course was attended by two officers from each of the State Departments, and was primarily designed to provide training in the techniques which could be used for critical examination of reproductive performance in the field. In addition, the opportunity was taken for a general review of current Australian research in sheep biology and husbandry.

At the request of the Australian Wool Bureau, the "Handbook for Woolgrowers" has been completely revised with assistance from other Divisions of C.S.I.R.O., officers of the several State Departments of Agriculture, and members of the various universities.

(b) *Regional Pastoral Laboratory, Armidale*

The laboratories of this establishment are located in the grounds of the University of New England, and other facilities are available at "Chiswick". Since the establishment of the Regional Pastoral Laboratory in 1947 a close liaison has been maintained with the University. In recent years cooperative investigations with the Faculty of Rural Science have been undertaken, and additional accommodation is provided in a joint C.S.I.R.O.–University building under construction. Due for completion later this year, these laboratories will provide opportunities for increased research effort.

The Divisions represented at Armidale are principally those of Animal Physiology and Plant Industry. Officers from these Divisions have been responsible for a broad program of animal and pasture research. Officers of the Divisions of Animal Genetics, Soils, and Mathematical Statistics, and of the Wildlife Survey Section, are also provided with accommodation and facilities.

2. Physiology of Reproduction

The level of reproduction in sheep flocks can be impaired by many factors which are the subject of several current studies.

(1) *Fertility of Rams.*—Study of the haemodynamic properties of the internal spermatic artery, previously reported, has been followed by an investigation at Prospect into the significance of this arterly to the maintenance of a decreasing temperature gradient between the body and the testes of Merino rams. Differences in temperature between the body and the testes, and the body and the scrotum (subcutaneous and surface temperatures) were recorded in rams standing quietly in the laboratory. These thermal gradients were reproduced in each ram after light anaesthesia, and intravascular gradients were measured simultaneously. In all experiments, when the average gradient between aortic blood and the deep testicular tissue was 5.6°C, blood in the artery on the testis surface was 5.1°C lower than aortic blood temperature, and venous blood after flowing through the pampiniform plexus was 5.4°C warmer than in the veins on the testis surface. Similarity between the arterial and venous gradients is indicative of an efficient heat exchange mechanism.

Adjustments in testicular venous and arterial temperatures rapidly followed changes in scrotal skin temperature. Thus subcutaneous temperature "sets" the testicular venous temperature which, in turn, regulates the arterial inflow temperature. Although the testicular vasculature can confer no greater benefit than the scrotal skin will permit, this arrangement allows the testis to respond quickly to changes in scrotal skin temperature. Efficiency of the scrotum as a heat-dissipating structure may be one factor closely related to the maintenance of fertility through periods of high environmental temperatures.

It has long been known that excessive environmental heat impairs the ram's fertility. This phenomenon is now being studied in more detail under controlled heat loads, and the magnitude of physiological responses to heat will be compared with changes in semen quality. Preliminary experiments indicated that other forms of stress might have adverse effects on spermatogenesis.

The amount of sweat produced per unit area of skin is being measured when dry air at a constant temperature is circulated around the scrotum in a closed circuit. The skin of this region proved capable of large increases in sweat production at raised air temperatures. Heating the scrotum was found to induce a marked panting response, followed by a rapid fall in rectal temperature of up to 1.5°C. This response is to be examined in more detail.

Variation has been reported to occur in the characteristics of ram semen. At present, it is not possible to distinguish normal physiological variations from those produced by unfavourable environmental conditions. Study has therefore commenced on seasonal changes in semen quality, on the influence of different methods of collecting sperm, and on physiological mechanisms which determine the capacity of a ram to withstand inimical conditions.

(2) *Fertility of Ewes.*—In the last annual report details were given of a method for controlling time of ovulation in ewes during the breeding season. This procedure has now been adapted at Prospect to the anoestrous ewe; good control of ovulation was achieved and oestrus occurred in most ewes, but the fertility following artificial insemination was very low.

Changes in dilatability of the ovine vagina have been measured during the breeding season and during anoestrus. An increase in apparent vaginal volume occurs at the time of oestrus. In anoestrus, the dilatability is smaller than at any time during the breeding season. Measurements of vaginal dilatability are useful in studies of the breeding season of ewes where the introduction of the ram is impracticable or undesirable, and can be used to distinguish between maiden and parous ewes, as the latter have much greater vaginal volumes.

Various dosages and combinations of progesterone, stilboestrol, and stilboestrol dipropionate were injected into ovariectomized crossbred ewes. The two stilboestrol compounds increased vaginal dilatability but progesterone had no effect. Progesterone with stilboestrol produced a rise and fall in vaginal dilatability characteristic of an ordinary dioestrous cycle in an entire ewe. As in the ordinary cycle, at the time of rise in volume, ewes mated with a ram. It appears that oestrogen is the hormone responsible for increase in vaginal dilatability at oestrus. An interesting seasonal variation was observed in response to hormone treatment. Vaginal tissue remained consistently responsive to hormone treatment, but sensitivity of "psychic" response varied with season.

In experiments involving artificial insemination of aged Merino ewes (from the New England Tableland), in which ovulation had been controlled by gonadotrophins, it became evident that cystic glandular hyperplasia of the endometrium was severely affecting fertility. This lesion has usually been associated with grazing of oestrogenically potent subterranean clover and has been a source of serious economic losses. A survey in New England has shown that incidence of cystic lesions ranged between 25 and 50% in aged ewes, slaughtered at abattoirs. The mechanism of this "clover infertility" is being examined, and a practical means is being sought of combatting the effects of ingestion of potent clover. Bioassay of pasture for oestrogenic activity is necessary in the study. Use of small animals in such bioassay has several disadvantages. Use of ovariectomized ewes and wethers as test animals is therefore being investigated. In the bioassays incidental observations were made on the differential incidence of vulvo-vaginitis. Ewes maintained on white clover were much more severely affected than those on other pastures.

(3) *The Neonatal Lamb*.—In previous reports, stress has been laid on the importance of numerous factors, other than infectious diseases, in the survival of new-born lambs. The frequency of heavy losses of lambs in severe weather has prompted detailed study at Prospect of the physiology of the neonatal lamb. A respiration chamber has been constructed to measure the metabolic rate of lambs under diverse conditions of temperature, wind velocity, and humidity. Lambs with a hairy birthcoat were able to conserve heat more readily than fine-coated lambs. Behaviour of hairy lambs was very variable, but some individuals were able to maintain normal rectal temperatures at 0°C with a concurrent heat production of only 1.6 times basal, as compared with 2.0–2.8 times basal in fine-coated lambs. These results are interpreted as reflecting coat insulation. Calculations based on skin temperatures in environments below 28°C show that the insulation of the tissues of the whole lamb is about 1.1 clo (120 kcal/m^2/24 hr/°C); insulation of the fleece plus still-air layer was 1.1 clo in fine-coated lambs and 2.2 clo in hairy lambs.

Heat production, in closely shorn lambs, was elevated much more than would be expected by removal of the fleece. Calculations based on skin temperatures suggest that thermal conductance of tissue in these lambs was much increased following shearing. Close shearing may cause cutaneous vasodilation by mechanical irritation, and this will be investigated as a possible factor contributing to "off shears" losses in adult sheep.

Effects of feeding, fasting, and age on metabolic rate have been examined. A marked rise in metabolic rate occurred at temperatures between 28 and −5°C within a few hours of feeding, in previously unfed new-born lambs. Thermal insulation in these lambs no longer appeared constant below the critical temperature. Metabolic rate fell to about pre-feeding levels after fasting for 12 hr, and constancy of insulation was again approached. Insulation in week-old lambs also appeared to vary below the critical temperature, even following 12–18 hr of fasting. Some variations can be explained by partial vasodilation of the extremities below the critical temperature, but it is not yet clear whether this is the result of feeding or a reaction of older lambs to a strange situation; changes in amount of heat lost by evaporation might also be involved.

In contrast to the metabolic rate of dry lambs in still air at 30 to −5°C, summit metabolic rate in new-born lambs is not increased by feeding; it remains remarkably constant during the first few days of life. However, when lambs are fasted, summit metabolism can decrease substantially even within 24 hr.

Further work was done on summit metabolic rate of crossbred lambs from ewes fed at various levels during late pregnancy. Summit metabolic rate, per kg of body weight, was independent of birth weight regardless of pre-natal nutrition. However, when expressed as rate per sq. metre of surface area, summit metabolism was dependent on body weight, e.g. 280 kcal/m^2 for a 5 kg lamb and 160 kcal/m^2 for a 2 kg lamb.

The respiration chamber has been modified to allow separate collection of water evaporated from the skin and from the respiratory tract. Below about 30°C heat lost by evaporation from these sites was about equal; above 30°C losses from both sites increased, but respiratory loss increased at the greater rate. The relative importance of each of these two sites was assessed by blocking evaporation from the other; it was concluded that while lambs sweat, the greatest contribution to evaporative cooling in hot conditions is from panting, and this mechanism possesses a great functional resource.

Heat production was measured in goitrous lambs from ewes fed methyl- or propylthiouracil during late pregnancy. The basal metabolic rate and summit metabolism were much below those of normal lambs. Normal levels were approached by the time that the lambs were a week old.

(4) *Behaviour of Ewes and New-born Lambs.*—Previous work has been extended at Prospect to include behaviour in a flock in which ewes were deliberately underfed during the last 6 weeks of pregnancy, giving an average weight loss of about 1.5 lb/week. No adverse effects were observed on maternal behaviour, but lamb vigour was reduced. Maternal behaviour and "sucking drive" in lambs were also observed. Udders of some ewes were covered for 11 hr after birth; their lambs tried to suck frequently during the first 3-4 hr, but thereafter sucking attempts became spasmodic and weaker, and when the covers were removed lambs were slow to suck. Ultimate survival of these lambs appeared to depend largely on maternal behaviour. Lambs held for 11 hr in a box, so that they could not even attempt to suck, generally reached the udder very soon after release. Lambs placed in a wind and kept wet for the first 4 hr of life, were, in general, slower to suck when replaced with their dams, than lambs kept warm and dry.

(5) *Sperm–Egg Interaction.*—In experiments at Prospect with mice having mutations at the *T* locus, data obtained on the segregation ratios of *t* and *T* or wild-type alleles indicate that, in females heterozygous at the *T* locus, eggs bearing a *t* allele are preferentially penetrated by sperm carrying a *t* allele. This finding has interesting implications in relation to the physiology of fertilization, as well as being further evidence that genes can express themselves in the phenotype of the gamete.

(6) *Effect of Nutrition on Oestrus and Conception.*—The relative importance of body condition and current level of nutrition on mating performance was assessed at Armidale in four groups of fine-wool Merino ewes. Ease of conception and number of twins were greater, and percentage of dry ewes lower, when ewes were flushed for 3 weeks before mating (whether in good or poor condition), than in

comparable groups of ewes which were not flushed. The number of twins (14%) was far greater in the good condition and with flushed ewes than in the poor condition and with flushed ewes (4%).

(7) *Control of Oestrus and Ovulation.*—In experiments at Armidale doses of 5–20 mg progesterone as daily or as double doses every 2 days for 16 days effectively controlled the oestrus cycle, except where ewes were within 4–5 days of oestrus. The interval from progesterone withdrawal to oestrus was increased in relation to size of the final injection.

(8) *Infertility of Ewes Grazing Clover Pasture.*—The presence of oestrogens in subterranean clover has been shown elsewhere to lead to infertility of ewes. Tests have been made at Armidale since 1957 to determine whether red clover had a similar deleterious effect; a control group of comparable ewes had no access to red clover. During the last two years, the lambing percentage of ewes grazing red clover has been lower than that of the control group.

An experiment is in progress to determine to what extent wethers and ovariectomized ewes may be used to indicate oestrogenic content of red and white clover pastures. Oestrogenic activity will be measured in terms of uterine weight and teat length increase in the ewes, and by bulbo-urethral gland weight and histology, and also by teat length increase in the wethers.

(9) *Fertility and Face Cover in Ewes.*—Lambing results from a previous experiment suggested that there was an inverse association between degree of face cover and fertility or fecundity of Merino ewes, but this was confounded by an inverse association between face cover and body weight, so that body weight might have been the only important factor. At Armidale in 1959, Merino four-tooth ewes, which were all adequately grown, were mated and wintered as one group. Lambing results were recorded and showed clearly an association between face cover as an index of genotype on the one hand, and fertility and fecundity on the other.

(10) *Effect of Shearing Prior to Lambing.*—The relative merits of lambing Merino ewes off-shears or in wool have been observed at Armidale over a period of 8 years. The overall comparison of results, in terms of percentage lambs marked, does not establish any clear-cut treatment difference.

(11) *Foetal Development.*—A comparison at Armidale of the development of Merino × Merino and Romney × Southdown foetuses has shown almost identical crown–rump measurements at foetal ages ranging from 50 to 140 days. However, at practically all ages Romney × Southdown foetuses and their organs were substantially heavier than those from Merinos, although the general growth pattern was similar.

After logarithmic transformation a linear relationship was shown between weight and age with a break in slope at about 80–90 days. Further chemical work is aimed at determining whether any difference can be found in the nature of the growth increments made before and after this stage.

These results are being used to interpret and amplify existing information on the effect of level of nutrition in pregnancy on lambing performance.

3. Endocrinology of Wool Growth

(1) *Wool Growth and the Anterior Pituitary Gland.*—In common with the investigation of the pituitary regulation of other processes, an essential requirement is the use of physically and biologically defined pituitary hormone mixtures. Results obtained with ill-defined material cannot be reproduced and give little guide to further investigation. Consequently research at Prospect into the anterior pituitary regulation of wool growth has been based on a program of preparation, electrophoretic analysis, and biological assay of pituitary hormones.

Zone electrophoresis on starch gel is one of the most promising methods available for the analysis of protein mixtures. Components separated in starch gel are being assayed for the different anterior pituitary hormone activities. The classical identification of different processes under anterior pituitary control with simple hormones may be incorrect. Thus four proteins with prolactin activity have been located. These proteins do not appear to result from chemical fractionation procedures, but it is unknown whether all are secreted by the pituitary. Similarly two proteins have been located with growth hormone activity. The location of thyrotrophic hormone, follicle stimulating hormone, luteinizing hormone, and adrenocorticotrophic hormone after starch gel electrophoresis is being investigated. The purest available preparations of these hormones, which are homogeneous by the criteria of boundary electrophoresis, sedimentation, and solubility data, show numerous components on starch gel electrophoresis.

(2) *Fractionation of Pituitary Proteins.*—Preparation and identification of extracts suitable for replacement therapy in hypophysectomized sheep forms a major part of the program at Prospect. Primary fractions prepared by differential centrifugation have been tested and some steps have been made to further fractionate these extracts. The development of a suitable assay technique for thyrotrophic hormone is still a problem, as is the purification of this hormone.

Growth hormone has been prepared from a mitochondrial fraction isolated by ultracentrifugation. Fractionation on a diethylaminoethyl (DEAE) cellulose column yielded 1.5 growth hormone/kg of fresh glands.

A more satisfactory method of preparing growth hormone is to add a simple extract of pituitary glands to a DEAE-cellulose column. Material which emerges unadsorbed already has a potency comparable to the standard preparation issued by the National Institute of Health. The hormone can be prepared on a large scale and with high yield.

(3) *Restoration of Wool Growth in Hypophysectomized Sheep.*—Hypophysectomy almost completely suppresses wool growth. In hypophysectomized sheep on a minimum maintenance dose of cortisone acetate, thyroxine (in a dose which will restore wool growth to normal in thyroidectomized sheep) restores wool growth to approximately 70% of the normal rate. Preparations with growth hormone activity tried at Prospect have failed to increase the response when given with thyroxine. This failure seems to be due to the presence of inhibiting factors in the preparation. A pure sheep-growth hormone preparation

made by a new method is at present being tested. Substantial restoration of wool growth is obtained with sheep thyrotrophic hormone preparations, but the contribution of factors other than the thyrotrophic hormone is being examined by measuring the response in thyroidectomized, hypophysectomized sheep. Earlier results, which require confirmation, showed that ox thyrotrophic hormone was ineffective in raising wool growth in hypophysectomized sheep.

(4) *Prolonged Wool Growth Response to Anterior Pituitary Extracts.*—Work at Prospect has demonstrated that following several weeks of daily injections of crude pituitary extract or pituitary growth hormone, stimulation of wool growth occurs which may persist for about a year following cessation of injections. Participation of the sheep's own pituitary in this response is indicated by the failure to obtain such a response in hypophysectomized sheep maintained on constant replacement therapy with thyroxine.

(5) *Wool Growth and the Thyroid Gland.*—Thyroidectomy reduced wool growth to about half the normal level and part of the suppression of wool growth caused by hypophysectomy can be attributed to thyroid atrophy. The measurement of thyroid activity by concentration of plasma-bound iodine is being developed at Prospect to examine the relation of individual and nutritional variations in wool growth to thyroid activity.

(6) *Wool Growth and the Adrenal Cortex.*—The wool growth response to thyroxine of adrenalectomized sheep maintained on a constant dose of cortisone acetate and deoxycorticosterone acetate has been measured at Prospect. In normal sheep the wool growth response to thyroxine may be reduced by increased cortisol secretion. Rapid disposal of injected cortisol in sheep suggested that analogues of cortisol might be relatively more potent in sheep than in other species. Preliminary evidence confirms this. Wool growth in one sheep was completely suppressed for 12 weeks following a single injection of dexamethazone. The relation between wool growth suppressing actions of adrenal cortical steroids and their effect on "break" in fleece is being examined.

(7) *Biological Assay of Pituitary Preparations.*—Work on interaction of thyroxine and growth hormone in the standard body weight assay for growth hormone has been completed at Prospect. The assay method for thyrotrophic hormone, using depletion of ^{131}I from the thyroid of the day-old chick, has been improved by additional recording of body background levels. However, this almost doubles the labour involved and limits the usefulness of the method. More recently a strain of chickens with a very high iodine uptake has been found and used successfully. A method involving the ^{131}I uptake of young rats whose endogenous secretion of thyrotrophic hormone has been suppressed by thyroxine implants is being investigated.

(8) *Estimation of Blood Levels of Pituitary Hormones.*—At Prospect antisera to several prolactin components, isolated by starch gel methods, have been prepared in the rabbit and showed good titres when tested by the precipitin method. However, this is not sensitive enough and it is hoped to develop the haemagglutina-

tion technique, which has a much higher sensitivity. Antisera are also being prepared against the two active growth-hormone components but so far no detectable titres have been obtained.

4. Skin and Fleece Development

(1) *Post-natal Development of Wool Follicles.*—A quantitative study has been made at Prospect of the post-natal development of follicle population, frequency of fibre shedding, and changes in skin thickness in Merinos and Southdown-Merino crossbreds. The animals were sampled from birth to approximately 2 years of age. In addition to the two main types of follicles (primary and secondary) a third type, called primo-secondary follicles, is recognized in some sheep. These follicles are usually situated on the secondary margin of the follicle group and are associated with sweat glands; arrector pili muscles are usually absent. It would appear that the follicles can form a continuous series in development, and the distinction between primary and secondary follicles should not be regarded as absolute.

(2) *Growth of Wool Fibres.*—The autoradiographic method has been used at Prospect to study the length growth rate of wool fibres. After an intravenous injection of (^{35}S) DL-cystine, radioactivity can be detected in the keratogenous zone of the follicles within 1 minute. Repeated injections provide a technique for measuring growth rates of individual fibres. This technique has been used in a preliminary study of the influence of nutritional changes on fibre growth. When the food intake was increased, the absolute increase in length growth rate was similar for all fibres. When nutrition level was reduced, length growth rate decreased in proportion to the initial rate. In terms of volume, although the changes were approximately proportional to the initial growth rate, a differential rate of response was observed in the largest and smallest fibres. Thus the length and diameter components of volume responded independently to the nutritional changes. Clipping had little or no effect on rate of wool growth. Reproducibility of autoradiographic length measurements by different observers had been examined; variance between observers was negligible compared with variance between fibres.

Periodicity of crimp formation has also been studied by autoradiographic methods in a mosaic-fleeced sheep, by using DL-cystine labelled with ^{35}S, and both types of wool had a crimp period of about 7 days. This technique has been extended to include normal animals undergoing a very substantial change in nutritional level (and therefore in rate of wool growth) in order to examine more critically the crimping period of fibres in a restricted anatomical region, and the possible relationship of crimp size to rate of fibre growth (linear rate, cross-sectional area, and mass).

(3) *Effect of Early Nutrition on Skin and Fleece Development.*—This experiment, carried out under pen conditions at Prospect, has established that severe undernutrition during pre-natal life results in reduction of mature body size and mature wool production. Drop in wool production was associated with a lower total follicle number, although density appeared little affected. Restricted

levels of early post-natal feeding resulted in a reduction of mature body weight and wool production. The latter effect appeared to be the result of a restriction of output per follicle (i.e. fibre size) rather than an effect on fibre or follicle number.

(4) *Activity of Wool Follicles.*—Investigations on the relationship between fibre growth and mitotic rate are continuing at Prospect. There is a high correlation between these characters, but fibre growth appears also to be a function of cell size. Size of cortical cells is being used as an index of follicle activity in comparisons of large and small fibres in two strains of Merinos at life-long high and low planes of nutrition; preliminary figures suggest that there are significant differences due to nutrition and between adjacent fibres of different size. The following additional comparisons are being made: between breeds, between fleece-types (including primitives), and between normal, doggy, and copper-deficient sheep. Evidence from a histological examination of the follicle papilla suggests that the number of dermal cells comprising the papilla has a major effect on both fibre cross-sectional area and length growth rate.

(5) *Pre-natal Development of Skin and Hair in Cattle.*—A histological study has been made at Prospect of the development of the skin and hair follicles in 22 crossbred (Zebu × Hereford or Zebu × Shorthorn) cattle foetuses, ranging in age from 77 to 263 days, and in three new-born calves. Initiation of hair follicles begins at about the 78th day of gestation in all regions. It continues to about the 140th day on the head, about the 160th day on the back, and about the 180th day on the midside. Three follicle types (first-, later-, and last-formed) are recognized. The first-formed follicles develop at about the same rate in the three regions studied, but they are slower than all the later- and last-formed follicles. All follicle types on the head are slightly more advanced than those on trunk positions.

5. Fleece Structure and Wool Production

(1) *Abnormal Crimping (Doggy Wool).*—Examination of sheep in different environments at Prospect has revealed that abnormal follicles are a widespread occurrence in the skin of sheep growing "doggy" wool. To date, the follicle abnormality has been associated with abnormal crimp in Merinos in Queensland, New South Wales, South Australia, and Tasmania, and in Polwarths in Victoria. Abnormal crimping has been observed in wools from Merinos and Corriedales in Victoria, and arrangements are being made to examine flocks in that State for follicle abnormalities.

The stages of crimp deterioration, noted in penned sheep, were also observed under field conditions. Detailed counts of follicles in skin sections have shown a positive association between the proportion of follicles that are abnormal and the degree of crimp deterioration. This association has been checked directly by plucking straight fibres and sectioning follicles longitudinally. In each instance of a follicle without a fibre there was enlargement of the outer root sheath. This finding makes possible more detailed measurements on doggy fibres.

As crimp deterioration in doggy wool is similar to that in wool grown on a copper deficient diet, means are being examined for distinguishing between the two. Breeding experiments have been initiated to test the possibility of an inherited tendency to the production of doggy wool.

(2) *Fibre Population in Sheep.*—The method developed at Prospect for estimating the total number of fibres in a fleece has now been refined. By allowing for loss of dust and vegetable matter from the small samples used to obtain greasy fibre weights, good agreement was found between the fibre numbers based on greasy and clean weights.

(3) *Fibre Diameter Measurement.*—The "cast" method is the most reliable for measurement of mean fibre diameter. Photographic standards have been prepared at Prospect for visual assessment of packing ratios in the casts. The error in assessment of packing ratio has thus been reduced considerably, and the main factor influencing overall accuracy is now the variation of fibre diameter within the sample. This aspect is being examined to try to develop an easy means of assessing variation.

(4) *Suint in Fleece.*—The source, amount, and nature of suint (cold-water extract of raw fleece) has been examined at Prospect in sweat-glandless and normal sheep. It has been found that suint is present in fleeces of animals lacking sweat glands; compared with suint from normal sheep, the amount is about one-fifteenth, the potassium content is about one-half, and the sodium content is unchanged.

Further information about the function of sweat glands was obtained from analysis of fluid accumulated within cysts experimentally implanted in the skin. It was assumed that the nature of the cyst contents reflected the activity of the sweat glands. A cyst in the skin of a normal sheep was distended with fluid containing a high concentration of potassium; a cyst in an animal with no sweat glands contained a small amount of a fluid low in potassium. With respect to level of potassium, cyst contents in the former case resembled intracellular fluid and in the latter, extracellular fluid.

The foregoing results indicated that sweat from sheep should be rich in potassium. Some tentative results were obtained with samples of sweat from the scrotum of a ram heated under controlled conditions. Potassium concentration was found to be high (80–280 m-equiv. potassium/l. sweat). In all samples the potassium : nitrogen ratio was close to eight. Together with the information on cyst contents, these results support the view that the major cattle cation in sheep sweat (an apocrine secretion) is derived from cytoplasmic fluid.

(5) *Nutritional Changes and Wool Growth.*—Under natural conditions in Australia, Merino sheep are often exposed to wide seasonal fluctuations in nutritive level. At Prospect the response is being studied of wool follicles to various dietary changes, including a long period at a low level of nutrition followed by a return to equilibrium on *ad lib.* feeding. The metric characters of the fleeces are now being measured.

(6) *Efficiency of Wool Growth.*—Using sheep at Prospect on a standard feeding ration, analyses of data on wool production and feed intakes have indicated

large differences between individual sheep in one flock, both in their appetites and the efficiencies with which they convert food to wool. Sheep having high wool-producing capacity tended to have larger appetites and to be more efficient converters than low wool-producing animals in the same flock.

More detailed experiments are being undertaken on influence of food intake and body condition on efficiency of wool growth. Three groups of sheep are being maintained in fat, medium, and poor condition respectively, and relations are being examined between wool growth, body condition, feed intake, body weight, and rate of body weight change.

A long-term experiment is in progress to study heritability of conversion efficiency and to establish two lines of sheep of different efficiencies. Lambs from the first mating have been reared. Weights of fleeces cut from ewes in the second year of the experiment are being examined to check repeatability of this character.

(7) *Fleece-Type Mutants*.—These sheep provide a source of material for studies on control of follicle initiation, rate of development, maturation, and capacity of mature follicles to produce wool.

The Merino felting lustre mutant has been found at Prospect to be controlled by a semi-lethal dominant gene. The action of the gene on foetal development, on the follicle primordia, and on the as yet unknown mechanism of fibre crimping in mature follicles is being examined. Normal crimping can occur in the fleece of the adult as well as of the neonatal heterozygous mutant.

Fleece type of the Merino low-ratio mutant is determined by a single gene, formerly believed to be recessive in action. There is now some evidence, however, that the heterozygote shows delayed initiation and maturation of follicles, though the adult fleece phenotype is near normal.

The phenotype of the Merino sweat-glandless mutant ("gog") is probably determined by a single factor, also with very much reduced effect in the heterozygote. The gog gene and the "low ratio" gene have been shown to interact in that the double heterozygote exhibits the "sweat-glandless" phenotype. Further matings have been made to elucidate the relationship between the two genotypes and to provide materials for further study of the mechanism by which initiation and development of follicles is influenced.

Sweat-glandless sheep have peculiar uses in other fields. They are used to study temperature regulation in new-born and adult sheep, and in the scrotum, and also in studies of the disposal or conservation of body-fluid electrolytes. The present breeding program aims also to provide sufficient material for such studies by other workers.

(8) *Carpet-Fleece Types*.—A further study at Prospect of carpet-type mutants in Corriedale sheep suggests that in this breed a dominant and a recessive gene can independently be responsible for the carpet-fleece phenotype. Semen of carpet-type Romney Marsh rams has been obtained from Massey College, New Zealand, for breeding experiments with Australian crossbred sheep.

6. Metabolism and Nutrition of Sheep

(i) *Metabolism in Pregnant Ewes**

(1) *Pregnancy Toxaemia.*—Metabolic response to insulin and ability to metabolize injected cortisol have been studied in field cases of pregnancy toxaemia in northern Tasmania. Results further support the hypothesis that these metabolic abnormalities are characteristic of a diabetic syndrome. As would be expected in diabetes characterized by adrenal hyperactivity, there was resistance to the hypoglycaemic effect of insulin, as indicated by a delay in the decrease in blood glucose following insulin.

(2) *Stress Experiments.*—Two forms of psychological stress have been used in experiments to study the effect of stress on plasma cortisol and blood glucose — stress of road transport (2–4 hr) and stress associated with removal to an unfamiliar environment (from paddock to single pens indoors). Both forms of stress are accompanied by pronounced increases in blood glucose and plasma cortisol in non-pregnant ewes. Plasma cortisol may increase to as much as 15 times the normal level of 0.5 μg per 100 ml plasma. Metabolic effects of 4 hr of stress in motor transport are no longer detectable after 20 hr, but effects may persist for 48 hr in sheep stressed by bringing indoors. In ewes fasted after bringing indoors, plasma cortisol may remain elevated for 96 hr in some ewes. In ewes fasted before transport stress, plasma cortisol reaches higher levels than in unfasted ewes. Plasma cortisol response to transport stress is considerably less in trained ewes which have been indoors for several months than in ewes at pasture, even when the former were fasted for 8 days before stress.

(ii) *Nutrition in Late Pregnancy*

An experiment with the following aims has been carried out at Prospect: (1) to study changes in *ad lib.* intake of roughage during pregnancy and lactation; (2) to investigate the use of blood ketones as a biochemical criterion of undernutrition of ewes in late pregnancy; (3) to obtain some measure of additional feed requirements necessary to prevent ketosis in late pregnancy with particular reference to differences between mono- and polytocous ewes.

Crossbred ewes in forward store condition and on a steady level of nutrition during pregnancy adjusted their metabolism to provide the additional requirements of a single lamb until about 2 weeks before lambing. Ewes with twins failed to adjust to meet the additional requirements after the 110th day of pregnancy. From present knowledge of foetal energy requirements, it can be predicted that the metabolizable energy of roughage, provided to meet the additional requirements of the foetus, will be inefficiently utilized. Additional roughage requirements necessary to prevent severe undernutrition, as indicated by onset of ketosis, are extremely high for ewes with twins, being as high as 75% of the ewe's own maintenance requirements in the last 2 weeks of pregnancy.

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Additional feed requirement in late pregnancy depended largely on the total weight of foetus(es). *Ad lib.* intake of roughage declined markedly in late pregnancy, particularly in ewes with twins. The results suggest that this decline may be largely due to space occupied by the developing foetus(es) and also that the decline may be greater in fat ewes than in ewes in forward store condition. The length of gestation period was shortened by about 4 days in these fat ewes. Twin lambs appeared to have a reduced chance of survival at birth, largely associated with birth weights below normal.

Blood ketones are unlikely to be a satisfactory indication of undernutrition in ewes carrying single foetuses under field conditions unless undernutrition is severe. The relative absence of ketosis in fat ewes in spite of reduction in feed intake in late pregnancy also restricts the usefulness of blood ketones as a field criterion. Loss of bodily condition may be readily detectable under conditions where ketosis is sufficiently severe to provide unequivocal evidence of undernutrition. Plasma-free fatty acid levels should be a more sensitive indicator of undernutrition in pregnant ewes.

(iii) *Digestion in the Rumen*

An automatic, flowing, dialysing, artificial rumen apparatus, which is mechanically satisfactory, has been constructed at Prospect. The biological results to date have not been up to expectation, but are superior to those obtained under otherwise identical conditions with non-flowing or non-dialysing systems or both. The main criteria of satisfactory functioning used to date have been the maintenance of numbers and of normal appearance of the ciliate and flagellate protozoa and of the larger bacteria. Since the flagellate protozoa seemed to be the most adversely affected of all groups, several attempts were made to culture them to study their biology. Very little is known of these organisms but the attempts were unsuccessful. At least some of the failure of the microbes to survive and multiply seems due to the nature of the dialysis fluid; substitution by clarified rumen liquor gave better though still not satisfactory results.

Study has commenced of the changes in rumen microbial population in sheep with changes in diet. This work is expected to give some information on the time needed for the microbial population to adapt to these changes, on the influence of quantitative changes on the population, and on maximum rates of division of the microbes.

(iv) *Metabolism of Cystine*

At Prospect intravenous doses of (^{35}S) DL- and L-cystine, both as the free amino acid and bound by disulphide bonds to plasma proteins, were given to sheep, and the fate of the ^{35}S studied. The bulk of non-peptide cyst(e)ine is bound to plasma proteins *in vivo* and there is a continous exchange between free and bound cyst(e)ine with a half-time of about 1 hour. It was not possible from these experiments to reach any conclusions regarding the possible role of protein-bound cyst(e)ine in keratinization of wool fibres. On the average approximately 30% of an intravenous dose of (^{35}S) L-cystine appeared in the wool grown during the 28 days after the dose, whether the cystine was given in the free or plasma protein-bound form, or whether specific activity was lowered by dilution of the dose with as much as 2 g of "carrier" L-cystine. Sheep, like other species, cannot use D-cystine for protein synthesis. The D-isomer was rapidly oxidized to sulphate and excreted, largely in the urine.

(v) *Mechanism of Incorporation of Amino Acids into Wool*

Incorporation of amino acids other than cystine into wool is being studied at Prospect. Trial experiments using (^{35}S) DL-methionine and (^{14}C$_9$) L-phenylalanine have been carried out. Analyses of samples of wool and plasma proteins, though not yet complete, show that the specific activity *v*. time curves for the wool were both rather different from those obtained with (^{35}S) L-cystine. Rate of fall of specific activity of the wool was much slower after the dose of methionine than after cystine, while the rate after phenylalanine was much faster.

(vi) *Conversion of Sulphate Sulphur to Wool Sulphur*

There seems no quantitative information on the extent of conversion of inorganic to organic sulphur in sheep. At Prospect as a first step towards providing such information, doses of aqueous $K_2{}^{35}SO_4$ were administered to sheep. Wool that was grown by a sheep on a standard ration contained 3% of the dose ^{35}S; a similar sheep receiving a dietary supplement of sodium sulphate gave no evidence of developing an adaptive rumen flora capable of increasing the utilization of sulphate sulphur for amino acid synthesis.

(vii) *Turnover Rates of Plasma Proteins*

Maximum values for half-times of the mixed plasma proteins in sheep have been estimated at Prospect by following the disappearance of ^{35}S from these proteins after dosing sheep with (^{35}S) cystine. The five values obtained so far range from 20 to 42 days. These times are long compared with other species of about the same size and may indicate a large amount of reincorporation of ^{35}S in the sheep. Techniques for separating the plasma proteins are being developed so that the turnover rates of individual proteins can be measured.

(viii) *Keratoses from Wool*

If cystine is incorporated into wool by two different mechanisms (synthesis of fibrillar and matrix proteins in cortical cells, followed by enrichment of the matrix only with sulphur) then the sulphur in the γ-keratose (i.e. the matrix) isolated from the first portion of radioactive wool grown after an intravenous dose of (^{35}S) cystine should have a higher specific activity than the sulphur in the α- or β-keratoses. The possibility of testing this hypothesis is based on the assumption that there is a delay of at least a few hours between the two processes. There is apparently no published information on the time taken for the cells to move from the mitotically active hair bulb to the keratogenous zone, but 12 hr seems to be a reasonable lower limit.

Several separations of the keratoses have now been carried out at Prospect with wool samples obtained at different times from sheep that had received intravenous doses of (^{35}S) cystine. The predicted non-uniformity in the specific activity of the sulphur has been observed. In the first portions of radioactive wool clipped, the specific activities decreased in the order γ-, α-, and β-keratose, and the sulphur in the wool produced later approached a uniform specific activity.

(ix) *Total Body Water in Sheep*

It has been shown by other workers that in monogastric animals, intravenous doses of tritiated water reach equilibrium with the body water within 2 hr. Total amount of body water can be calculated, knowing the amount of tritium injected and the specific activity of the water at equilibrium. At Prospect it has now been found with sheep that, after an intravenous dose, a longer time is required before equilibrium is reached, i.e. before the specific activity of the water in the rumen liquor equals that of the water in blood samples taken at the same time. The longer mixing time is presumably due to the large volume of water in the rumen. As a routine, blood samples are taken 5, 6, and 7 hr after an intravenous injection of tritiated water and the mean specific activity used to calculate the total body water. When tritiated water was injected into the rumen at least 9 hours elapsed before the radioactivity was evenly distributed.

As an aid to determination of body composition in living sheep, an apparatus is being developed for measurement of body volume; with body weight, this measurement gives an estimate of specific gravity. The technique used is air displacement in a sealed container; a high degree of accuracy is essential for satisfactory use of the apparatus.

(x) *Energy Metabolism*

Energy metabolism of new-born lambs has been studied at Prospect for some years. This work has now been extended to include adult sheep. Two respiration chambers have been built to provide for determination of balances of energy, nitrogen, and carbon. These are closed-circuit chambers with automatic controls for environmental conditions, feeding, and lighting. Special harness has been designed for quantitative collection of urine and faeces from both ewes and wethers. Experimental sheep are trained in metabolism cages in conditioned surroundings comparable to those in the respiration chambers, so that errors due to stress of strange surroundings are minimized.

In preliminary digestion trials with standard rations, errors in analytical procedures and in the daily measures of faecal losses were determined. From these data, it is easy to estimate the length of an experiment needed to obtain a particular level of precision and the degree of replication required in analyses for balance studies.

An experiment is now in progress to determine the energetic efficiency and maintenance requirements of fat and thin adult sheep.

(xi) *Protein Biosynthesis in Cellular Particles*

Rat liver mitochondria were investigated as a site of protein synthesis in the cell. It was found that isolated, washed mitochondria actively incorporated radioactive amino acids into their protein when incubated in a sucrose–potassium chloride medium which contained phosphate ions, a complete mixture of L-amino acids, an energy substrate (succinate or α-ketoglutarate), magnesium ions, adenosine monophosphate, and an adenosine triphosphate-acceptor system (hexokinase and glucose). Active incorporation of amino acids could be maintained for 2 hr and was dependent on oxidative phosphorylation.

In contrast to results obtained by other workers with isolated microsomes, cell sap was not required in the incubation medium and the incorporation reaction was not inhibited by ribonuclease. However, it was shown that most of the ribonucleic acid associated with mitochondria was not removed by ribonuclease. Evidence was obtained for the presence in mitochondria of amino acid activating enzymes of the type occurring in the cell sap and known to be essential for incorporation of amino acids into the protein of isolated microsomes. (This work was undertaken at the National Institute for Medical Research, London.)

(xii) *β-Globulins of Sheep Plasma*

Several new β-globulin types have been discovered by zone electrophoresis on starch gel. The gene frequency of the β-globulin type in various flocks is being examined at the Ian Clunies Ross Animal Research Laboratory in collaboration with the Division of Animal Genetics.

(xiii) *Digestion and Metabolism in Grazing Sheep*

Study of grazing sheep presents difficulties requiring novel procedures for solution. In studies at the Ian Clunies Ross Animal Health Laboratory the collection of excreta from unrestrained animals has indicated that there are considerable variations in food intake of different sheep exposed to climatic stresses such as driving rain. More detailed information has therefore been sought on grazing behaviour. Apparatus has been developed for recording jaw movements which provide indications of the times spent grazing, ruminating, or resting. Jaw movement opens a switch on a small radio transmitter strapped on the sheep's back, and resulting signals are continuously recorded in the laboratory. This is especially useful in that reliable observations can be made at night without any disturbance created by an observer.

Satisfactory techniques have been available for collection of faeces from grazing animals, but collection of urine has proved very difficult. As the latter is essential for study of nitrogen metabolism, new methods have been developed. The most satisfactory apparatus to date is a urine cart consisting of a stainless steel cylinder on wheels towed behind the sheep. Urine is delivered to the tank by tubing from a collector held by harness under the sheep's prepuce. Tests have indicated that with sheep grazing a good clover–rye grass pasture, the presence of the cart has no appreciable effect on fodder intake. Concurrent measurements of nitrogen excretion in faeces and urine and of wool growth provide an estimate of nitrogen intake.

7. Sheep Diseases

(1) *Posthitis in Wethers*.—In previous reports, accounts have been given of the incidence and the local treatment of this economically serious disease. Antiseptic local treatment was only partially successful and improved methods were sought. At the Regional Pastoral Laboratory, Armidale, it has now been found that wethers receiving testosterone prophylactically (100 mg implants at 3-monthly intervals) show a considerable reduction in the incidence of posthitis; testosterone produces a concurrent increase in body weight and greater production of greasy wool. After 12 months, the incidence of external ulceration in treated wethers was 18% compared with 71% in the controls; none of the treated wethers had internal ulceration, while 29% of controls were affected.

Wethers with established lesions were treated therapeutically with testosterone either alone or with local antiseptic treatment. Results have been very encouraging and further tests will be carried out.

(2) *Diseases of the Urinary Tract*.—Two important diseases of the urinary tract (calculi and posthitis) appear to be essentially of nutritional origin. Apparatus is now being developed at Prospect for the quantitative collection of urine from grazing sheep. For critical work on renal function it is desirable to have a method for complete collection of urine over short periods of time; surgical procedures are therefore being worked out for bilateral ureteral exteriorization.

Special attention is being devoted to deposition of calcium carbonate, as this is reputedly the commonest form of calculus. In specimens examined, carbonate was present as concentric layers of radial crystals of calcite, and no distinct nucleus could be detected.

It has been suspected that high protein intake by grazing wethers precipitated occurrence of posthitis. However, neither high protein intake nor continuous intravenous infusion of urea produced lesions in pen-fed wethers. Feeding of lucerne hay was followed by the appearance of preputial lesions.

8. Bioclimatology of Sheep

(1) *Cold Stress in Sheep*.—The wind tunnel at Prospect for experiments with control of temperature, humidity, and air movement, has been improved by a louvre system which gives good control of wind speeds of 1–11 m.p.h.

A calorimetric apparatus for measuring the thermal insulation of the fleece and an artificial sheep to hold it have been completed. Its most important characteristic is rapidity in operation. Experiments are in progress on the insulation of closely shorn and $\frac{1}{2}$ in. Merino fleeces in various winds, with a view to assessing protection against cold after ordinary shearing and after shearing with a snow comb. Insulation of fleece in still air is about 4.4 clo per in., which is within the upper part of the range of insulation of mammalian coats. Its value in wind at a point on the skin depends on factors which interact with one another; so far, those studied have been wind velocity, angle of sheep to the wind, and length of fleece.

When sheep are exposed to cold, an increase in skin thickness quickly occurs. Initially, this increase is due to a change in water content, but later there is a change in skin histology which is now being examined in detail.

(2) *Seasonal Variation in Wool Growth.*—The experiment previously reported is continuing. Merino sheep at Prospect appear to have less seasonal rhythm than that exhibited by sheep of various breeds employed by earlier investigators. The Southdowns have a normal rhythm. At the present, unfinished stage of the investigation, evidence has been obtained that the rhythm is partly temperature dependent and partly light dependent. There are considerable differences in the behaviour of the individual animals. The geophysical dependence of shedding, in those areas of the skin where massive shedding occurs, seems to be different from that of wool growth, and resembles that for reproduction.

(3) *Control of Reproductive Season of Ewes.*—Previous work had indicated that seasonal variation in sexual activity of Merino ewes was not due to length of day (hours of daylight). Current experiments in special climate rooms have shown that, when seasonal photoperiod is removed, environmental temperature does not immediately control the sexual season. The experimental sheep, Merinos and Southdown, were maintained in a constant, equatorial day length (12 hr 40 min) with the thermal seasons reversed; the normal seasonal behaviour pattern has been maintained. This may indicate the existence of an autonomous rhythm, but effects of other geophysical factors cannot be excluded.

9. Ecology of Australian Sheep

Changes in total numbers of sheep, numbers of breeding ewes, mean percentages of lambs marked, and average cuts per head of sheep in each shire in Western Australia, South Australia, New South Wales, and Tasmania are being studied at the Ian Clunies Ross Animal Research Laboratory.

Averages for the 5 year period 1945–50 have been compared with those for the 5 year period 1951–55. The most notable increases in total sheep numbers, numbers of breeding ewes, total numbers of lambs marked, percentages of lambs marked, and average cuts per head have occurred in Western Australia.

Increases in total sheep numbers have also occurred in those shires in eastern Australia where extensive areas of pasture have been improved, but generally the mean productivity of the animals has not shown very marked increases.

10. Drought Feeding

Experiments on drought feeding of sheep have continued at the Ian Clunies Ross Animal Health Laboratory in collaboration with the New South Wales Department of Agriculture at the Veterinary Research Station, Glenfield. Financial support has been provided from the Burdekin Bequest Fund by the New South

Wales Graziers' Association. The principal aim of these experiments has been to devise diets and feeding procedures which are economical and enable sheep to survive in severe drought conditions. Emphasis has been placed on several main features: the use of low quality roughage; supplementing poor roughages with small amounts of high quality feeds or with urea as a protein substitute; feeding sheep at long intervals — once or twice per week; recovery of sheep after prolonged feeding on drought rations; use of grain rations with no roughages; and breeding performance of ewes after an extended period on survival rations. Recommendations for use under field conditions have been embodied in a special technical communication prepared in cooperation with State Departments of Agriculture.

11. Internal Parasites of Sheep

(1) *Phenothiazine-Salt Lick.*—In a 3 year experiment at Armidale, breeding ewes have been grazed on sown pasture at stocking rates of 4 and 8 sheep per acre; half the ewes had continuous access to a mixture of phenothiazine and salt (1 : 12) while the controls had access to salt alone.

No consistent differences in total worm-egg counts from the ewes were recorded until the spring of 1958, when the provision of phenothiazine-salt mixture, and also the lower rate of stocking, were associated with lower levels of worm infestation. During the spring of 1959 the value of this mixture was even more apparent, but no differences due to rate of stocking developed. An important effect of providing phenothiazine for the ewes was a reduction in the incidence of parasitism in their lambs. The lower level of worm infestation in both ewes and lambs was mainly referable to reduction in populations of *Haemonchus contortus*, but also of *Oesophagostomum* spp. The possibility that continuous phenothiazine therapy may have induced worm resistance is under investigation.

(2) *Evaluation of Anthelmintics.*—"Neguvon" (*O,O*-dimethyl-1-hydroxy-2,2,2-trichloroethyl phosphonate) was shown at Armidale to be highly effective against *Haemonchus contortus* and safe for sheep at dose rates of about 2.5 g per 100 lb liveweight. At this dose rate and at higher levels some effect was also observed against *Ostertagia* spp. Dose rates of 5.0 g or more per 100 lb often produced signs of toxicity and sometimes death, especially if swallowed into the abomasum after stimulation of the oesophageal groove reflex.

The level of lungworm infestation in fine and medium wool Merino weaners was significantly reduced by treatment with "Dictycide" (cyanacethydrazide). Lungworm larval counts fell to a low level within 3 days of treatment, and remained low for 3 weeks. Larval counts increased in the control sheep. As in a previous experiment no measurable clinical response followed treatment.

Carbon tetrachloride, given in therapeutic doses, was found to impair liver function as judged by the bromsulphthalein dye clearance test. Liver function returned to normal in about 1 week.

(3) *Immunization of Lambs.*—In cooperative experiments with the McMaster Laboratory, tests at Armidale have been made on the immunization of lambs

against *Haemonchus contortus* by administration of infected larvae attenuated by X-irradiation. The irradiation level of 60,000 roentgen was sufficient to prevent development to maturity of all male infective larvae and most female larvae. Under conditions of heavy natural challenge, treated lambs have shown a slightly lower *Haemonchus* infestation than controls.

12. Pasture Intake and Digestibility

Further data have been accumulated at Armidale for the estimation of pasture digestibility from faecal nitrogen and fibre percentages, and the diurnal cycle in faecal nitrogen excretion is also being examined.

Accuracy of estimation of faeces output by the chromic oxide (Cr_2O_3) marker technique has been compared with the accuracy of bag collection. Seventy-two estimates of faecal organic matter output of individual sheep, over periods ranging from 7 to 14 days using chromic oxide, averaged 104 ± 12% of the actual amounts. If the coefficient of variation of daily bag collections of faeces organic matter is approximately 20–25% it would be necessary to make total collections for 4–5 days in 10 in order to improve on the accuracy of the continuous chromic oxide dosing method.

Since faeces from grazing sheep may contain up to 65% mineral material all analyses and estimates of intake are based on ash-free organic matter. From the concentrations of chromic oxide, nitrogen, and "normal-acid-fibre" in the faeces organic matter, an estimate of digestible organic matter (D.O.M.) may be made.

For pastures with a wide range of organic matter digestibility (from 35 to 85%) the digestible energy content (energy in feed minus energy in faeces) averages close to 4.7 ± 0.3 kcal per g D.O.M. The high degree of uniformity means that measurement of D.O.M. is virtually measurement of digestible energy.

Pasture intake of Merino and Romney ewes was measured just prior to lambing. It was found that, in spite of increased foetal demands, pregnant ewes ate less than comparable non-pregnant ewes of the same flock.

Feed requirement for maintenance of Merino wethers has been determined under pen feeding and grazing conditions. Sheep have been kept at virtually constant liveweights of approximately 60, 80, or 110 lb for 6 months. Lower body weights were maintained by high stocking rates on short pasture. In pen-fed sheep, given cut pasture, maintenance intakes of digestible organic matter were proportional to body weight as expected. However, a strikingly different picture was found in grazing sheep; wethers at 110 lb liveweight required approximately 400 g digestible organic matter (D.O.M.) per day; by contrast, similar wethers of body weight 60 and 80 lb required 700 and 800 g D.O.M. per day respectively.

10

Division of Biochemistry and General Nutrition

1. General

The Division of Biochemistry and General Nutrition grew out of the former Division of Animal Nutrition, and since its establishment in 1944 has been able to make substantial contributions to a basic understanding of nutritional problems associated with the ruminant animal.

Understanding and correction of nutritional disabilities imposed on flocks and herds by climate and terrain is of particular importance in Australia, which is primarily dependent on animal industries associated with sheep and cattle production. The main course of the Division's investigations has been concentrated on problems related to wool production, but some of the results of research in this field apply equally well to meat production. In certain projects the Division employs cattle as experimental animals.

The headquarters of the Division of Biochemistry and General Nutrition is in Adelaide, and the Division has field stations at O'Halloran Hill and Robe in South Australia. This chapter describes current research projects in progress at the Division of Biochemistry and General Nutrition.

Other investigations bearing on animal nutrition are undertaken in the Division of Plant Industry (*see* Chapter 3); the Division of Tropical Pastures (*see* Chapter 4); the Division of Animal Genetics (*see* Chapter 7); the Division of Animal Physiology (*see* Chapter 9); the Fodder Conservation Section (*see* Chapter 15); and the Division of Land Research and Regional Survey (*see* Chapter 13).

2. Nutrition and Wool Production

The series of experiments, begun two years ago, on the separate influences that protein status and fuel value of rations exert on the rate of wool production by Merino sheep are nearing completion. These experiments are part of an investigation of factors responsible for the extra heat evolved after protein consumption — a phenomenon referred to in classical physiology as the specific dynamic effect of proteins. This project is closely associated with studies of the thermodynamics of food utilization (cf. following sections).

3. Energy Metabolism

Studies of the overall energy transactions of ruminants, which provide an understanding of the animal as a converter of matter and energy, are being extended and reorientated to explain factors associated with growth and development in relation to improvement of meat production.

Experimental work is nearing completion to provide data for compilation of the complete energy balance sheets of animals necessary for the study of the specific dynamic effect.

Sensitive instruments are being developed to record small changes in concentration of oxygen and carbon dioxide in the ventilation stream of the open circuit calorimeters employed in these studies of energy transactions. Such instruments to be of value must be capable of estimating concentrations of carbon dioxide and of oxygen with a precision of one part in 40,000. These instruments present difficult design problems, and until these are solved reliance must continue to be placed on normal gas analysis techniques.

It has been demonstrated that the efficiency of conversion of foodstuffs varies from nil (when the animal consumes an amount necessary merely for maintenance) to 66% (when the animal consumes about three times its maintenance requirement). For most foodstuffs the latter is close to the capacity of the digestive organs. This emphasizes the importance of appetite and the factors that control appetite.

4. Microcalorimetry

The microcalorimeter has been developed to a form satisfactory for the continuous study of the heat production of microbial systems.

The instrument is continuously self-balancing, heat production in a reaction vessel being matched by electrical heating of an identical balance vessel. The vessels may be sterilized and are inert towards the systems to be studied. Provision is made for stirring, sampling, and maintenance of a controlled atmosphere.

A continuous record of the electrical heat supplied to the system is presented on a strip-chart, and the calorimeter has proved to be an extremely sensitive and stable instrument.

Preliminary studies on heat production by pure cultures of *Streptococcus faecalis* and *Lactobacillus plantarum* have been carried out. Resting cell suspensions of both *Lactobacillus plantarum* and *Streptococcus faecalis* fermenting glucose to lactic acid at 37°C produce about 31 kcal of heat per mole of glucose utilized. From the data obtained in these experiments, the standard free energy change (ΔF) for glucose fermentation at 37°C was calculated to be -30.3 kcal per mole. The fermentation of glucose by growing cells of *S. faecalis* has also been studied with respect to heat production. These experiments indicate that very young cells of the organism produce less heat per mole of substrate utilized than do older cells in the same culture. This finding is the reverse of that found in 1934 by other workers doing similar studies.

The calorimeter is now to be used to study heat production during the metabolic processes occurring within the sheep rumen.

5. Microbiological Processes in Ruminants

By the use of suitable markers in the rumen contents, the rapid conversion of plant nitrogen, from wheaten and lucerne hays, to microbial nitrogen was demonstrated — the greater part of the conversion being completed in 6–8 hr. Microbial nitrogen was principally (90%) bacterial when a mixed diet was fed, but on a diet comprised of lucerne only, the proportion of protozoal nitrogen in the microbial fraction increased from 5 to 40% during the course of the day. In material reaching the omasum, conversion of plant to microbial nitrogen had always reached an extent equal to the maximum found in the rumen.

In sheep fed on the mixed ration the use of polyethylene glycol and lignin as inert markers indicated that fluid passed from rumen to omasum more rapidly than solid plant residues; but nitrogen to lignin ratios in the three compartments of the stomach were nearly constant for the period 5–10 hr after feeding. Passage of nitrogen appeared to keep pace more nearly with the flow of solids than with that of the fluid.

The work with individual fatty acids introduced into the rumen has been completed for sheep fed on wheaten hay. The results — showing the gross rates of production of acetic, propionic, and butyric acids in these animals — have been prepared for publication. The net rates of production cannot be determined directly by this method *in vivo* because of the interconversion of a part of the acids during the fermentation, and because of other changes after their formation. The second phase of the work has therefore been to examine the fermentation *in vitro* to find the extent of such changes.

In vitro fermentations involving about 1 litre of whole rumen contents have been employed, the material being taken from sheep fed on wheaten hay. Two types of fermentation procedure have been used. In the first, no material was removed from the fermentation vessel during the 2-hr test period. In the second type an overflow of rumen fluid was arranged so that the volume in the vessel remained constant despite continuous inflow of artificial saliva. The latter type allows calculation of rates of production in the same way as in the work originally carried out *in vivo*, and so permits direct comparison of results.

The experiments are still incomplete, but sufficient data are now available to suggest that it will be possible to apply the findings to the problem of determining the net production rates for the fatty acids in the normal rumen.

Rumen Hemicellulose Fermenters.—A further study of such organisms has been made and an isolated pure culture has been characterized. The organism in question was tentatively identified as a new species of the genus *Bacteroides*.

6. Carbohydrates and Stereochemistry

(1) *Paper Ionophoresis of Carbohydrates*.—Prospects are good for a fairly complete understanding of the factors that determine the relative rates of migration of carbohydrates in paper ionophoresis in borate buffers. A further study of results obtained in the Division of Biochemistry and General Nutrition, and of results

published by others, has suggested working hypotheses about the nature and stability of borate complexes likely to be formed from common carbohydrates. Experiments have been designed to test these hypotheses.

(2) *Formation of Carbamates from Amines.*—The work on the formation of *N*-carboxy derivatives (carbamates) from primary and secondary amines in the presence of sodium hydroxide and carbon dioxide has been completed.

(3) *Behaviour of Boric Acid on Paper Strips.*—Free boric acid is surprisingly volatile when dispersed as a spot on filter paper. Boric acid from a spot may be transferred in part to an adjoining strip of paper at room temperature, or to another part of the original strip. The effect is accentuated by methyl or ethyl alcohol, probably because volatile borate esters are formed. It is possible to remove the boric acid from a mixture of carbohydrates and boric acid by applying spots of the mixture to paper and exposing them to methanol vapour. It seems possible in this way to eliminate the interference by boric acid that normally hinders the paper chromatography of carbohydrates prepared by reduction with sodium borohydride, or by elution after paper ionophoresis in borate buffer.

Boric acid volatilized from one part of a paper strip seemed to be selectively adsorbed on those parts that contained spots of various α-hydroxy acids (citric, tartaric, malic) or salicylic acid. This was surprising, because a careful examination by paper ionophoresis showed that, contrary to implications in the literature, these acids do not form very stable borate complexes. The effect was found to be due to a very strong potentiation by these acids of the usual curcumin test for boric acid. In the presence of α-hydroxy acids, boric acid gives a visible colour at much lower concentrations, and the colour persists far longer, than in their absence. This observation has led to the development of an improved spray reagent for boric acid, which incorporates citric acid with curcumin.

(4) *Complexes of Polyhydroxy Compounds with Metal Cations.*—When some neutral polyhydroxy compounds were submitted to paper ionophoresis in dilute solutions of sodium salts, it was found that *cis*-inositol and, to a lesser degree several other inositols, form cationic complexes with sodium ions. The complexes form only to a limited extent, even with *cis*-inositol, but their presence is easily detected. Complexing of *cis*-inositol also occurs, but still more weakly with potassium and lithium ions, and apparently with sulphate ions (anionic complexes). This seems to be the first evidence for formation of complexes between alkali-metal ions and neutral polyhydroxy compounds in dilute aqueous solution. In *cis*-inositol, three hydroxyl groups are especially well placed for formation of tetrahedral or octahedral complexes with metals of appropriate ionic radius.

7. Carbohydrate Metabolism and Renal Function

The utilization of carbohydrate and lower fatty acids by adult sheep and young lambs has received further attention.

The use of ^{14}C-labelled glucose has provided a means of estimating the size of the glucose pool in sheep and lambs, and of extending knowledge of the role of insulin in these animals.

Study of the previous nutritional history of sheep in relation to tolerance to administered acetate has indicated the need for further research into problems associated with diet and interrelationships between carbohydrate and fatty acid metabolism.

Various factors concerned with utilization of acetate are being investigated, and the role of the liver studied together with that of enzymes important in liver metabolism.

Observations on certain aspects of kidney function in the adult sheep are being continued and current experiments have revealed the nature of the mechanisms which determine the capacity of sheep to tolerate waters of high salinity.

8. Salt Tolerance and Potability of Stock Waters

The third experiment in this series is complete. The fourth experiment is now nearing completion, in which sodium chloride in saline drinking water was partially replaced by calcium chloride. There were six groups each of six wethers. Two received respectively rainwater and 1.3% sodium chloride, and the remaining groups 0.05, 0.10, 0.20, and 0.30% calcium chloride, together with 1.2, 1.2, 1.1, and 1.0% sodium chloride respectively. Some difficulty was experienced in the early stages of the experiment in securing adaptation of the sheep to the experimental regime. Now after more than one year on the various treatments little difference has been found between the food consumption, weight increase, or wool production of any of the groups. Slight differences only, probably not significant, have been observed in the concentrations of electrolytes in the plasma. Indications, therefore, are that, under the conditions of the experiment, the sheep have been able to drink water containing up to 1.0% sodium chloride plus 0.3% calcium chloride without harmful effect.

Plans are now being made for the fifth experiment in the series. In this experiment the sodium chloride in the drinking water will be partially replaced by sodium carbonate and bicarbonate.

9. Microbiological Assays

(1) *Vitamin B_{12}*.—The difficulty, experienced in the *Lactobacillus leichmannii* assay of the vitamin B_{12} content of liver samples, of the presence in extracts from the livers of vitamin B_{12}-deficient sheep of substances which adversely affect the growth of *L. leichmannii*, has been overcome by adsorption of the vitamin on charcoal followed by elution with boiling 65% acetone.

Critical comparisons of the concentrations of vitamin B_{12} in samples of plasma and serum prepared from the same samples of blood indicated no difference within the normal tolerances of the assay procedures.

(2) *Growth of* Lactobacillus casei.—The growth of this organism has been employed for some years in the Division of Biochemistry and General Nutrition as a means of estimating folic acid. This microorganism requires riboflavin, panto-

thenic acid, and other substances. When folic acid is limiting, the growth response to added increments of folic acid is enhanced by asparagine. When riboflavin is limiting, asparagine has an inhibitory effect.

10. Intermediary Metabolism of Sheep

(1) *Metabolic Lesion of Vitamin B_{12} Deficiency.*—Events of intermediary metabolism which become deranged when the stores of vitamin B_{12} in the liver of the sheep fall below a certain limiting concentration have been discussed in previous reports. Briefly, as the state of deficiency worsens the animal loses progressively its capacity to deal with propionic acid.

In the metabolic channels of the higher animals propionic acid is converted to succinic acid prior to being utilized for the production of energy. The course of this conversion is propionyl–CoA* → methyl malonyl–CoA → succinyl CoA, the first step involving condensation with carbon dioxide and the second an isomeric rearrangement of the carbon atoms in the methyl malonate.

In vitro experiments have proved that in homogenized preparations of livers from vitamin B_{12}-deficient sheep the conversion of propionyl–CoA to methyl malonyl–CoA is unimpaired. The isomeric change of the methyl malonyl–CoA to succinyl–CoA is, however, impeded to such an extent that methyl malonyl–CoA accumulates in the reaction mixture. A normal rate of clearance may be re-established by the addition of a vitamin B_{12}-containing coenzyme isolated from normal liver tissue. The metabolic lesion in the vitamin B_{12}-deficient animal is thus a failure of methyl malonyl isomerase due to shortage of its coenzyme. Such a lesion, involving the inability to deal efficiently with propionic acid, is serious in a ruminant, which normally derives more than one-third of its energy requirements from the metabolic degradation of this simple fatty acid.

(2) *Vitamin B_{12} and Folic Acid Deficiencies.*—Studies of the relationship of vitamin B_{12} and folic acid deficiencies on the metabolism of histidine by sheep and rats as judged by the urinary excretion of formiminoglutamic acid have been continued. Those with the sheep have been concluded.

The ability to deal with the degradation products of histidine was enhanced, for a short time, in certain vitamin B_{12}-deficient sheep by the administration of folic acid, but subsequently the amount of formiminoglutamic acid excreted in the urine exceeded that prior to treatment with folic acid. Administration of vitamin B_{12} completely restored the ability to deal with the products of histidine catabolism in all of the animals examined.

A supplement of methionine to vitamin B_{12}-deficient rats (rendered folic acid deficient by administration of aminopterin) restored their ability to deal with the degradation products of histidine.

From some anomalous results obtained with both rats and sheep, it would seem that under certain circumstances histidine is degraded by a route other than that involving formiminoglutamic acid.

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* CoA, coenzyme A.

11. Provision of Cobalt to Ruminants by Heavy Pellets

Heavy pellets comprised essentially of cobaltic oxide and china clay — Formula A (for sheep) and Formula B (for cattle) — have been adopted with success under many different conditions of husbandry practice. They have been demonstrated to fulfil effectively the cobalt requirements of flocks and herds grazing on the extensive areas of cobalt-deficient grazing lands now known to be distributed throughout the world.

When licences for the manufacture of pellets according to Formula A were granted, it was understood that employment of pellets of those specifications should be considered an interim measure to meet, *pro tem.*, the requirements of pastoralists who were anxious to have immediate access to a ready and simple means of combatting cobalt deficiency and phalaris staggers. At that juncture it was already realized that the Formula A pellet had two disabilities, viz. (*a*) its weight (5 g) and specific gravity (sp. gr. 3.9) were not such as would ensure its continual retention in the ruminant's forestomachs under *all* conditions of grazing, and (*b*) in certain circumstances its surface became inert and ceased to function. Whether the failure resulted from rejection or from loss of function, such disabilities were not considered particularly serious when the pellets were employed to prevent cobalt deficiency *per se*. Cessation of the supply of cobalt, from whatever cause, would lead in due course to a loss of condition which could readily be detected and the deficiency made good by redosing. When employed as a prophylactic against phalaris staggers, however, loss of a pellet or failure of its function could be disastrous, for to provide effective protection against this malady a continual supply of cobalt to the rumen flora must be ensured.

Although these disabilities are very real in particular instances, Formula A pellets have, in general, proved to be of great value to the pastoralists and graziers in Australia and elsewhere during the past three years.

Further investigations have indicated means of overcoming the disabilities. Testing of improved pellets under a variety of grazing conditions has now proceeded to a stage at which recommendations have been made for their employment in the pastoral industry.

The hazard of loss of pellets by regurgitation has now been reduced to negligible proportions by increasing the weight of each pellet from 5 to 10 g, and by increasing the specific gravity from about 4.0 to about 5.0. To achieve this the use of china clay as a carrier of the cobaltic oxide has been abandoned in favour of finely divided iron, which is now incorporated to the extent of 40% of the overall weight.

Pellets are pressed from this mixture and suitably baked. To ensure that the surface of the pellet is maintained in a condition which will continue to yield sufficient cobalt to meet the full requirements of the rumen flora, an abrading device has been evolved. This "grinder" is essentially a solid cylinder of iron or steel, similar in size and shape to the pellets, with its surface suitably roughened by screw-cutting or by knurling. When swallowed by a ruminant, an object of this nature accompanies the pellet during its excursions within the forestomachs. In the swirl of the paunch contents, frequent collisions between the two objects provide the gentle attrition necessary to renew the surface of the pellet. An engineer's grub screw of appropriate size serves this purpose admirably.

The new, heavier pellets and their accompanying grinders are still being subjected to long-term tests under a variety of field conditions and with experimental animals in pens. The results already to hand have led to a recommendation that the use of pellets made and administered according to Formula A (for sheep) and Formula B (for cattle) should be superseded by the use of pellets made according to Formula C (for sheep) and Formula D (for cattle), together with their appropriate grinders.

The cobalt pellets are widely employed in husbandry practice. In Australia the right to manufacture them is granted freely to all firms who undertake to fulfil the specified requirements. Overseas rights have been let to a commercial firm. The income derived by the Wool Research Trust Fund from royalties on overseas sales of cobalt pellets is already in excess of £25,000 per annum.

Preparation for Survey of Areas Limited by Cobalt Deficiency.—The ready accessibility of a cheap and simple means of providing extra cobalt to ruminants renders it important to assess the extent and distribution of areas in Australia where production efficiency of flocks and herds is impaired by failure of available fodder to provide the cobalt necessary to meet animal requirements. Experience is indicating more and more terrain which is insecure in respect to cobalt. It is imperative that the situation in Australia be carefully examined with sound experimental methods.

For this reason an extensive survey has been planned. Techniques have been developed for collection of blood and tissue samples from grazing animals and for pretreatment of these at the site of collection so that they may be transported to the laboratory without deterioration. Sensitive assay methods for the estimation of vitamin B_{12} content of these tissues have been developed and a study is being made of relationships between vitamin B_{12} status of the animal and vitamin B_{12} content of its blood.

12. Plant Nutrition

An investigation is being made of the uptake, distribution, and loss of cobalt from *Phalaris tuberosa* and *Poa pratensis*. The former species is being studied because of its importance as a pasture plant and its association with phalaris staggers, the latter because of its reported tendency to accumulate cobalt more readily than many other grasses.

The plants were grown in solution cultures which contained cobalt labelled with radioactive isotope ^{60}Co. Distribution of labelled cobalt was determined in the plant by radioautographs. Cobalt did not appear to reach higher concentrations in *Poa* than in *Phalaris*, so far as this comparison was possible in the initial studies, and its distribution appeared similar in the two species. The radioautographs showed that cobalt present in fully expanded leaves was not distributed evenly there, but tended to accumulate in veins and particularly at leaf tips. The concentration of cobalt in the leaf sheath was usually much higher than in the lamina of the same leaf. The concentration in young leaves was much higher than that in the laminae of fully expanded leaves.

Accumulations of cobalt were found in the leaves where they had been deliberately cut or bruised. This result was quite striking and was to be observed whether leaves were mutilated in this way before or after labelled cobalt was added to the culture medium. It will be of interest to determine whether such accumulations occur in leaves which are repeatedly cropped, as they would be under grazing.

Evidence was obtained suggesting that some cobalt is lost from leaves by guttation at leaf tips. Results of experiments designed to provide evidence of mobility of cobalt within plants were inconclusive.

II

Division of Entomology

1. General

The Division of Entomology is the main centre in C.S.I.R.O. for research on insects. The headquarters of the Division is at Canberra. The Division has a Biological Control Station in Sydney, and field stations at Trangie, N.S.W., and at Ingham, Qld. The Division cooperates with the Animal Research Laboratories on such problems as sheep blowfly and cattle tick; with the Division of Plant Industry on certain pasture problems; with the Division of Forest Products in study of pests of timber; and with the Chemical Research Laboratories in insecticide investigations.

There is an increasing awareness in the rural industries that control of insects by insecticides as now practised in Australia requires critical examination. The steadily increasing cost and difficulty of insect control in orchards could make fruit growing in some areas uneconomic. Resistance to insecticides has already appeared in a number of agricultural, horticultural, and pastoral pests, notably in the sheep blowfly and the cattle tick. Pasture pests, many of which until recently could be tolerated, now require regular treatment with insecticides. The Division of Entomology is paying particular attention to these problems.

In March 1960, Dr. A. J. Nicholson retired after 25 years as Chief of the Division of Entomology. He has been appointed a Senior Research Fellow to enable him to continue his work on population dynamics. Dr. D. F. Waterhouse was appointed to succeed him as Chief.

Following a conference on eucalypt defoliation by phasmatids in commercial forests and catchment areas in New South Wales and Victoria, the Division is embarking on ecological studies of these insects. A proportion of the costs of this work will be borne by the Snowy Mountains Hydro-Electric Authority and the River Murray Commission.

The large-scale introduction of fruit fly parasites from Hawaii was completed at the end of 1959. Fruit samples are now being collected in the liberation area to determine whether the parasites have become established.

The following grants have been received by the Division during the year to support research in special fields: a grant from the Dairy Research Grants

Committee for study of nematode parasites of curl grubs; a grant from the United States Public Health Service for research on insect tissue culture; a grant from the Rural Credits Development Fund to bring to Australia Dr. J. T. Slykhuis of the Canadian Department of Agriculture to report on viruses in cereals and grasses in Australia.

The following distinguished scientists from overseas visited the Division during the year to assist in various projects: Dr. V. F. Eastop of the British Museum; Professor E. S. Hodgson of the Zoology Department, Columbia University; Dr. F. J. Simmonds, Director of the Commonwealth Institute of Biological Control; Dr. B. P. Uvarov of the Anti-Locust Control Centre.

The Division has been engaged in cooperative work with the New South Wales Department of Agriculture on the Australian plague locust, and on other investigations with the Australian National University, the University of Melbourne, the University of Sydney, the Queensland Department of Public Lands, the Victorian Department of Lands and Survey, and the Western Australian Forests Department. Once again the assistance given by the University of Hawaii and the United States Department of Agriculture in the fruit fly project is gratefully acknowledged.

2. Insect Physiology and Toxicology

(1) *Digestion of Wool by Insects*.—The larva of the clothes moth *Tineola bisselliella* possesses an enzyme which catalyses the reduction of L-cystine by reduced triphospyridine nucleotide (TPNH). Reduced diphosphopyridine nucleotide (DPNH)-linked cystine reductase and DPNH- and TPNH-linked glutathione reductase of somewhat lower activity are also present in the clothes moth extracts. These reductases probably play a very important part in the process whereby clothes moth larvae digest wool.

(2) *Chitin-Protein Complexes*.—Samples of chitin have been prepared from cuticles of several insects and crustacea, from cuttlefish shell, and from the skeletal pen of a squid. In every case protein was bound by covalent bonds to the chitin so forming stable complexes (glycoproteins). Glycoproteins from different sources contained differing amounts of chitin and protein, the ratio of chitin to protein varying from 1 : 1 to 20 : 1. Protein appears to be linked to the chitin through aspartyl or histidyl residues or both. Amino acid composition of the protein components of the glycoproteins has been determined. The cuttlefish and squid preparations contained cystine, but sulphur-containing amino acids were not present in the insect or crustacean preparations. It is probable that chitin does not occur uncombined with protein.

(3) *Composition of Oothecae of some Orthoptera*.—Oothecae of *Periplaneta americana* contained 6.5% calcium and this was the only major cation present. Only 35% of the calcium was present as calcium oxalate and in view of the absence of other anions the remainder may be present as a calcium-protein complex. Oothecae of *Blatella germanica* and *Orthodera ministralis*, although containing much less calcium, gave similar results. Chitin is absent from the oothecae of these Orthoptera.

(4) *Hardening of the Cuticle.*—Work is continuing to provide direct evidence on reactions during formation of the hard cuticle. To avoid complications caused by the presence of chitin, use is being made of hardened oothecae of the cockroach *Periplaneta americana.*

(5) *Chitinase.*—Breakdown of undenatured chitin by cockroach preparations (blood, digestive juice, cuticle brei, extract of cast skins, and saliva) and by an extract of whole termites has been demonstrated. Optimum pH for cockroach digestive chitinase lies between 5.4 and 6.0 and products of digestion of chitin with this preparation were *N*-acetylglucosamine, probably its dimer and trimer, and a trace of glucosamine. With all other preparations *N*-acetylglucosamine and a trace of glucosamine were found. Deacetylase activity could not be detected in the cockroach preparations.

(6) *Blowfly Taste Receptors.*—Taste receptors on the labellum of *Lucilia cuprina* were studied by electrophysiological methods. Latent periods between time of stimulation and appearance of the first nerve impulse were obtained for two types of chemosensory cells, viz., those which respond to sugars and those which respond to electrolytes and other substances rejected by the fly. Both types of chemosensory cells respond to bending of the chemoreceptors' hair when in a non-adapted state. A third neuron associated with the hairs is also stimulated by mechanical stimulation.

(7) *Blowfly Oviposition Responses.*—Oviposition responses of *Lucilia cuprina* to mixtures of indole and ammonium carbonate have been further studied. Indole and carbon dioxide appear to act as oviposition stimulators through different receptor sites.

(8) *Neurosecretion from Cockroaches.*—Pharmacological tests show that the corpora cardiaca of *Periplaneta americana* contain a substance which has at least some adrenaline-like characteristics. Stressing the roach reduces the quantity of active substance remaining in the glands.

(9) *Flight Muscle Sarcosomes.*—The method for isolating sarcosomes from the flight muscle of the sheep blowfly, *Lucilia cuprina,* and subsequent preparation of a sarcosome membrane fraction by the action of sodium desoxycholate has been improved to yield a purer membrane fraction free from fat contamination. Sarcosome membranes contain approximately 10% of lipid which is an aliphatic hydroxy-ketone. Sterols and phospholipids are absent. Further work on the structure of the membrane lipid is continuing.

(10) *Insect Cuticular Lipids.*—Infrared spectroscopy, gas chromatography, and other physico-chemical methods are being used to study the waxes of insect cuticle. Initial work is being done on the grease from the cuticle of cockroaches.

(11) *"The Biochemistry of Insects".*—Proofs of this book, written by an officer of the Division, have been read, and it is expected to appear in print in the near future.

3. Insects and Viruses

(1) *Cauliflower Mosaic Virus.*—Properties of cauliflower mosaic virus have been studied and an effective purification procedure developed. The resulting preparation is monodisperse in the electron microscope and in the analytical ultracentrifuge. Virus particles have a diameter of about 400 Å and a sedimentation coefficient of 214S. Electrophoretic analysis, however, shows that the preparation contains three components which have not been separated. With the use of purified virus preparation it has been demonstrated that cauliflower mosaic virus is non-persistent. The fluorescent antibody technique has been used to localize the virus in the infected leaf.

(2) *Barley Yellow Dwarf.*—Work on the ecology of barley yellow dwarf has resulted in the discovery of a new vector, *Macrosiphum avenae miscanthi.*

(3) *Other Viruses.*—Other investigations in progress include: the preparation of a list of aphid vectors of virus diseases; the discovery of the first cytoplasmic polyhedrosis in an Australian insect; the demonstration that aphids are not concerned with the transmission of tomato spotted wilt virus which causes a disease of peanuts in Queensland; and work on the site of multiplication of an arbor virus in the mosquito vector.

(4) *Insect Tissue Culture.*—After six years of concerted effort, a cell line from insect tissue has been established in culture. Insect tissue culture may now be said to have been established on a firm basis. The cell line originated from the ovarian sheath of pupae of *Antheraea eucalypti.* It has now been subcultured 21 times in a complex medium containing over 50 constituents. Several cell types occur and cloning has not yet been accomplished. Attempts are now being made to grow viruses in the cells.

4. Population Dynamics

(*a*) *Theoretical and Laboratory Studies*

With the use of laboratory populations of the Australian sheep blowfly, *Lucilia cuprina,* influences are being studied which are known to operate upon populations of insects and animals in nature. Populations have been found to possess a high degree of resilience, being able to adjust themselves to inimical influences, provided these do not exceed a critical intensity. The mechanism underlying this resilience is being studied, together with the effects of environmental influences. Strains of flies with different properties are being selected to study the way in which populations adjust themselves to change in properties. It has been shown that populations remain stable in spite of very great changes in properties, and selection tends to produce properties which are far better than those necessary to cope with prevailing environmental conditions.

(*b*) *Field Studies*

(1) *Psyllid Investigations.*—Recent numerical increases of *Cardiaspina* sp. in study areas near Canberra have been associated both with poor synchronization

between the searching periods of encyrtid parasites and occurrence of psyllids vulnerable to parasite attack, and with spring weather which appears to be unfavourable either for parasite searching or survival.

In study areas in Victoria where, after outbreaks, psyllid numbers have decreased greatly and remained low for up to seven generations, host-parasite synchronization has been almost optimal for one of the encyrtids. Average rate of parasitism by this species has been relatively very high, and the proportion of hosts destroyed appears to be directly related to their population density. The parasite concerned may play a significant part in prevention of further psyllid multiplication.

(2) *Eucalypt-Defoliating Insects.*—The drought of the past summer provided a valuable opportunity to study the effect of this type of stress on both the sawfly, *Perga affinis*, and its host trees. Drought during the critical periods of adult emergence and egg hatching can bring about a catastrophic reduction in the abundance of the insect.

Laboratory studies on the survival of *Perga* under differing temperature and humidity regimes have proved useful complements to field studies on the distribution and fluctuating abundance of sawfly. Ability of *P. affinis* to reproduce parthenogenetically has been established.

(3) *Aphids.*—Population dynamics of aphid infestations are being investigated so that the value of natural enemies and of strains of host plant resistant to aphids can be accurately assessed in future biological control work. Preliminary investigations are being made on the cabbage aphid, *Brevicoryne brassicae*, and the grain aphis, *Rhopalosiphon padi*.

5. Insect Systematics

The Division's dipterist retired at the end of 1959 and a grant has been arranged to enable him to complete his work on several families. A new dipterist commenced work in May.

The main lines of work at present are:

(1) *Diptera.*—Work has continued on the Calliphoridae, the large and important family of blowflies. This has proved a major undertaking, and the manuscript of a large monograph is now almost ready. Some work has been done on certain other groups of the Diptera.

(2) *Hymenoptera.*—Work is continuing on the systematics of certain important groups of parasitic Hymenoptera, chief among which are some families of the Chalcidoidea. Several major revisions are nearing completion.

(3) *Lepidoptera.*—A revision of the pyralid stem-borers (Schoenobiinae) of rice and related plants in Australia has now been completed.

Steady progress has been maintained in the preparation of manuscripts on the Australian Tortricidae (leafrollers). Extensive changes in the previously accepted classification will result from this study which, for the first time, places due emphasis on genitalic structure.

(4) *Scarabaeidae*.—Reorganization of the Division's collection of Coleoptera, particularly the Scarabaeidae, has continued, and identifications made of over a thousand specimens at the request of other institutions.

(5) *Acridoidea*.—The revision by J. A. G. Rehn and the cytotaxonomic study of the Morabinae are being continued. A first paper resulting from the study of type specimens in overseas museums has been published.

(6) *Psyllidae*.—The generic status of some important Australian Psyllidae has been clarified and this work is ready for publication.

(7) *Aphids*.—Substantial work has been done on the preparation of a key to the known Australian aphid species, and several new species are being described.

6. Ecology of Orchard Pests

(1) *Queensland Fruit Fly* (*In cooperation with Department of Zoology, University of Sydney*).—A large orchard at Wilton, N.S.W., has been leased for field studies on ecology of the fruit fly, and a long-term project on the population dynamics of the fly has been commenced. Estimations have been made at weekly intervals throughout the entire fruiting season of the number of larvae present in the orchard. Techniques for obtaining similar data for pupae and adults have been worked out.

Useful information has been obtained about movements of adult flies in the field. The hypothesis that immature adult flies leave an orchard soon after they emerge could not be confirmed by experiment.

In cooperation with the New South Wales Department of Agriculture, tests have been made of a powerful attractant specific for male fruit flies. This substance promises to be extremely useful, particularly for early detection of small populations in the southern States.

Studies have been commenced on a population of fruit flies in east Gippsland, Victoria. This project may provide valuable information on factors limiting the spread of the fly in the southern States.

Experiments are continuing on the overwintering habits of the fly and on its nutritional requirements.

(2) *Codling Moth*.—Investigations were continued near Canberra on the nature of the interaction between properties of this species and characteristics of its environment. Under conditions of optimum environmental favourableness, population density is governed by competition for larval food and cocoon shelter. Availability of cocoon shelter is normally so limited as to prevent the annual populations from exhausting their supply of fruit prematurely, i.e. before the end of the season. Thus the relative scarcity of cocoon shelter tends to minimize seasonal fluctuations of population density by maintaining the abundance of overwintering larvae at a fairly constant level from year to year. Favourableness of the

environment for codling moth may be significantly reduced by the suppression of cocoon shelter, and this suppression may be achieved rather easily.

Effectiveness of a glyodin-ryania spray program on apples was investigated further in the Australian Capital Territory. Commercially acceptable protection against black spot, light brown apple moth, mites, woolly aphis, and codling moth was obtained, and it is believed that the fortnightly rate of application adopted last season may be considerably reduced without undue risk.

7. Locusts and Grasshoppers

(1) *Australian Plague Locust.*—During the spring of 1959, Dr. B. P. Uvarov, leading world authority on locusts and grasshoppers, visited Australia at the invitation of C.S.I.R.O. He has suggested that the proposed Commonwealth–State trial of the strategy of outbreak suppression should be replaced by a control policy committed to this strategy and implemented by an independent interstate locust control service. This is in line with the Division's past recommendations for the control of this locust. Pending policy decisions by the bodies concerned, routine assessments of the population level in the Bogan-Macquarie outbreak area are being continued. The soil survey is finished and appropriate maps are being prepared.

(2) *Solitary Grasshoppers.*—Field and laboratory studies on *Phaulacridium vittatum* have been terminated. Factors involved in the ability of this species to persist in a wide variety of pasture types, despite frequent occurrence of seasonal droughts, have been evaluated in the light of current views on the numerical regulation of populations. The study has indicated the factors which play a significant part in the population dynamics of other pest species of grasshoppers. The pest status of *P. vittatum* has been assessed and some recommendations have been made for its control.

8. Pasture Caterpillars

Studies have continued to evaluate the significance of such environmental factors as temperature (both constant and fluctuating) and photoperiod in inducing reproductive diapause in the cutworm *Agrotis infusa.* Delays in development comparable with those occurring in natural populations have not been produced experimentally.

Field observations and sampling have thrown further light on the seasonal occurrence and pest status of *A. infusa* on the Southern Tablelands of New South Wales. Should favourable rains occur during late January and February, pasture growth is sufficient for development of larvae hatching from eggs laid by post-aestivation adults. These can produce adults, with very pale hindwings, in late autumn and early winter, but few eggs are laid by them. Should rains be delayed until March or later, larvae cannot reach maturity until the following spring, and low winter temperatures usually cause heavy mortality. Larval outbreaks therefore occur only during mild winters following good autumn rains.

9. Lucerne Flea and Red-legged Earth Mite

(1) *Insecticidal Control.*—Systemic insecticides have given excellent results in small-scale tests against both pests. Seed treatment with "Thimet" and "Sayfos" prior to sowing produced seedlings which remained toxic for up to 2 months. This method has application in the protection of such crops as pea, vetch, and lucerne. "Thimet" granules and "Sayfos" sprays also appear effective.

(2) *Lucerne Flea Ecology.*—Adverse conditioning of the environment by high lucerne flea densities did not occur when the fleas were replaced every 4 or 8 days. Conditioning did occur when the same fleas were left together for 12 or 16 days. The fleas themselves must undergo some "conditioning" before they can influence their environment.

Diapause eggs are produced in spring. Provided moisture is available, these eggs may hatch at any time from about mid January onwards. The 21°C upper limit for the hatching of aestivating eggs of *H. destructor* does not apply to lucerne flea eggs.

10. Phasmatids

Preliminary work has commenced on ecology of the phasmatids which, for some years, have been defoliating eucalypts in New South Wales and Victoria.

11. Biology and Control of Cattle Tick

Since chemical control measures remain the primary means of combatting cattle tick, a study is being made of the action of acaricides on the tick, and the nature, biochemistry, and inheritance of resistance to acaricides.

(1) *Biochemistry of Acaricide Resistance.*—Susceptible and resistant strains have been compared biochemically to find differences which might account for resistance, e.g. arsenic-resistant ticks from New South Wales were compared with susceptible ticks in respect to: sulphydryl groups (active centres of several vital enzymes) with which arsenic is known to react; citric acid, a key compound in carbohydrate metabolism involving sulphydryl enzymes; and keto acids (by-products of arsenic poisoning).

The metabolic fate of DDT in ticks is being studied in two ways: by incubating DDT with homogenized eggs and larvae; and by feeding susceptible and resistant ticks on the same animal orally dosed with DDT to determine their content of DDT and metabolites. Egg homogenates do not appear to metabolize DDT, but larval homogenates do, in amounts increasing with larval age. Homogenates of resistant larvae metabolize more DDT than those from susceptible larvae. The product of metabolism is not yet known. Concentrations of DDT in adult ticks were higher than in the blood of the DDT-dosed animal on which they had fed, but there was no difference between resistant and susceptible strains in this respect.

(2) *Action of Acaricides.*—Effects of acaricides on ticks were further studied. DDT treatment of engorged adults had progressively less effect on egg production

the later it was applied. DMC, a compound previously found to affect the viability of eggs, was injected into adults and rendered 90% of their eggs non-viable. Wax contents of these eggs was 67% below normal, suggesting that DMC interferes with the female's egg-waxing process.

(3) *Genetics of Resistance.*—DDT resistance in a strain of ticks from central Queensland has proved to be controlled by a single, incompletely recessive, autosomal gene. Similar experiments on inheritance of dieldrin resistance have indicated so far that resistance is a dominant characteristic.

(4) *Persistence of Acaricides on Cattle Hair.*—Seasonal changes are being studied in the persistence of DDT on the hair of cattle, in relation to period of protection against tick reinfestation.

(5) *Effect of Tick Resistant Cattle on Cattle Tick Populations.*—Thirty Australian Illawarra Shorthorn heifers have been studied over 12 months for degree of tick resistance and found to exhibit consistent differences. They have been separated into herds containing either only resistant or only susceptible animals to study the effect on tick populations.

(6) *Tick-free Areas.*—In one case where drinking water was alleged to confer tick resistance on cattle, experiments showed the water had no effect. Ants have been further shown to affect tick numbers in some cases, particularly where soil type favours large ant populations of particular species.

(7) *Pasture Spelling and Strategic Dipping.*—Experiments at Ingham have shown the great value in tick control of spelling pasture for 3 months to allow the tick population to die out naturally. A strategic dipping program in which the cattle were dipped five times at three-weekly intervals resulted in the tick infestations remaining low for 13 weeks afterwards.

(8) *Tick Survival.*—In these studies three diverse sites in north Queensland have been used in the planning of strategic dipping and pasture spelling regimes.

12. Sheep Blowflies

(1) *Ecological Studies.*—*Chrysomyia rufifacies* appears annually to repopulate large areas from which it dies out over the winter, and precise information is being sought on the permanence of the zones of distribution of this and other species. Additional data have been gathered on the regional and seasonal incidence of various species of blowflies, and studies of overwintering have been carried out, so far chiefly with the species of *Lucilia*.

(2) *Diazinon Formulation Deterring Oviposition by* Lucilia cuprina.—Field evidence suggested that *L. cuprina* could detect and strike areas on sheep which had been missed during spraying with a diazinon formulation. Insectary and laboratory tests showed that the flies were prevented from laying on areas treated with the formulation and moved around until they found an untreated area. However, the oviposition deterrent effect resulted from use of a particular solvent in the formulation, and, when another solvent was substituted, the flies laid normally on fleece carrying a heavy deposit of diazinon.

13. Insect Pests of Stored Products

Investigations into the effects of oxygen depletion, and carbon dioxide accumulation on the khapra beetle *Trogoderma granarium* were carried out overseas as material was not available in Australia.

An experimental air-tight grain silo is being constructed by a Sydney firm, and financed by a grant from the Wheat Industry Research Council.

Research has been undertaken on percussion for the control of insect pests of grain. This method has proved very effective and acceptable to industries producing pulverized products such as flour, but existing machines cannot effectively be used for whole grain, owing to excessive breakage of the grain. Determinations have been made of forces required to kill grain weevils in all stages from egg to adult when these are inside the grain, and of those forces that cause breakage of sound grain of various moisture contents.

14. Biological Control

(*a*) *Weed Problems*

(1) *St. John's Wort* (Hypericum perforatum).—A shipment of *Chrysomela* beetles was sent to South Africa late in 1959, but only minor distributions have been carried out in New South Wales by the Division.

(2) *Ragwort*.—Twelve thousand adults of the seed fly *Pegohylemyia jacobaeae* were released in Gippsland, Vic., this year. Prospects of establishing this species seem good. Further observations were carried out on the larval population of the cinnabar moth *Tyria jacobaeae* in Gippsland.

(3) *Noogoora Burr*.—The present series of investigations on *Mecus saturnina* and *Nupserha antennata* under quarantine conditions has been completed. If *M. saturnina* became established in coastal Queensland it would not be expected to colonize drier inland areas of the State but would probably spread into the southern States. *N. antennata* has not damaged burr as severely under insectary conditions as it does in India. The species seems more suited, however, to the drier conditions of western Queensland.

Preparations have been made to reopen work on *Dectes spinosus*.

(*b*) *Insect Problems*

(1) *Brown Vegetable Weevil* (Listroderes obliques).—Improvements have been made in the technique of culturing the three species imported from South America on *Tersilochus*, larval parasites of this weevil. Liberations of all three species have been made in several States.

(2) *Queensland Fruit Fly* (Strumeta tryoni).—The liberation of parasites from Hawaii concluded in October 1959. In all, 466,000 adult wasps were liberated in Queensland, New South Wales, and Western Australia, and 17,000 wasps on Lord Howe Island. *Opius oophilus*, the major fruit fly parasite in Hawaii, now appears to be established at three locations in New South Wales, and one in

northern Queensland, recoveries having been made 8–11 months after the last liberations of the species in the areas concerned.

(3) *Aphids.*—With the cooperation of Bureau of Sugar Experiment Stations and various colleagues, aphids are being trapped in various parts of Australia to obtain continent-wide comparisons of the timing and duration of aphid flights with a view to the prediction of crop infestation for later biological control experiments.

(4) *Nematode Parasites of Curl Grubs.*—Stocks of one species of insect-parasitic nematode have been imported from the United States and the basic equipment acquired for research in this new field. Preliminary studies on the rearing and manipulation of nematodes have been carried out.

(5) Dionus pumilio.—Several large consignments of this predator of the balsam woolly aphid have been sent to the Canadian Department of Agriculture this year.

15. Termites

(1) *Laboratory Studies.*—The first stage of a survey in cooperation with the Western Australian Forests Department of the natural durability of certain Western Australian commercial timbers to termite attack has now been completed. In laboratory tests with *Nasutitermes exitiosus*, *Acacia acuminata*, *Eucalyptus marginata*, and *E. redunca*, in that order, have proved the most resistant. Cross-checking tests are now being made in the laboratory with *Coptotermes lacteus* and in the field with *Coptotermes* sp.

A cooperative test with the Division of Forest Products has started to evaluate various preservatives against *N. exitiosus* and *C. lacteus*. Results to date indicate that preservatives containing arsenic are definitely superior to those based on boron compounds or copper-chrome mixtures, and that *N. exitiosus* is much more tolerant to boron-based preservatives than *Coptotermes* sp.

Further work on the termite-proofing of concrete indicates that addition of 0.5% aldrin to the mixing water will proof "no-fines" concrete as effectively as 0.5% dieldrin. Cost of the treatment is, therefore, reduced by half.

Laboratory tests have also been made on various scaling compounds, wrapping tapes, and plastics. Results include a wrapping tape which resists termite penetration, and substantiation that surface hardness of plastics cannot be used to predict resistance to termite attack.

(2) *Field Studies.*—Surface treatments have shown that 5% pentachlorphenol failed against *N. exitiosus* in the fourth year. Against *C. lacteus* only 1% dieldrin, 10% sodium arsenite, and creosote remain effective after 2 years.

Soil treatment tests have continued and all materials mentioned in last year's Annual Report remain effective.

(3) *Termites in Forest Trees.*—Gallery studies have been made on a colony of *Coptotermes acinaciformis* in an old blackbutt stump. This colony was the source of infestation in three living blackbutt trees, previously thought to have been attacked by a colony in an adjacent living tree.

Studies have been made of temperature in living trees, with and without infestation by *C. acinaciformis*. A difference of 25°F between nursery temperature and tree temperature extended only 1 or 2 in. from the edge of the nursery.

With the cooperation of the Forestry Commission of New South Wales, assessments are being made of the economic losses caused by the termite *Porotermes adamsoni*, decay, and fire, in alpine ash forests during logging operations at Bago during 1959–60.

16. Ants

In comparing the effectiveness of diazinon and dieldrin, it was found that dusts and sprays containing diazinon caused high initial kill, but did not prevent reoccupation of treated nests by adjacent colonies. Colonies treated with dieldrin spray were completely controlled and nests remained free of ants.

17. Insecticides

(1) *Genetics of Resistance*.—Selection experiments on strains of houseflies have continued in the study of insect resistance to insecticides. Two distinct genetic types of DDT resistance have now been found. One is of the usual kind, autosomally controlled; the other is unique, being sex-limited to males and probably associated with the Y chromosome. These resistant strains have been widely tested with other insecticides, and their resistance has proved specific to DDT.

An association had previously been found between resistance to DDT and rate of maturation, such that selection for late maturation discriminated against susceptible individuals. However, recent work has shown that, whereas selection for early maturation eliminates autosomal resistance, it does not eliminate Y-chromosomal resistance which appears to be genetically independent of maturation rate. These methods of selection have been applied to develop several substrains of known genetic constitution upon which future studies on the biochemical mechanisms and genetic origin of resistance will be carried out.

(2) *Structure and Activity*.—A further 11 amides of long-chain fatty acids synthesized at the Chemical Research Laboratories have been tested on houseflies as part of the study of relationships between chemical structure and insecticidal activity (*see* Chapter 34, Section 4(1)).

12

Wildlife Survey Section

1. General

The C.S.I.R.O. Wildlife Survey Section was established to study Australian wildlife problems. In every country of the world mammals and birds, both native and introduced, affect primary production and other human activities in a variety of ways. In Australia, what may conveniently be termed wildlife problems range from that of the rabbit, the country's most serious pest, to the mutton-bird, on which a small but valuable local industry depends. Native animals, such as marsupials and waterfowl, may be pests at times in parts of their ranges while calling for conservation elsewhere.

The headquarters of the Wildlife Survey Section is at Canberra. The Section has a field station at Albury, N.S.W., and has officers working in various localities throughout the Commonwealth. The Section works in collaboration with State Departments, the Antarctic Division of the Department of External Affairs, and universities, while most of its field investigations would be impossible without the assistance of individual landholders.

The Division of Entomology undertakes research on insect life in such aspects as population dynamics and biological control (*see* Chapter 11).

2. Mammal Investigations

(*a*) *Rabbit Investigations*

(i) *Myxomatosis*

All major field studies of myxomatosis have now been concluded. The Section is still maintaining observations on the performance of the disease, and its effect as a factor regulating rabbit population levels will be checked by those members of the staff who are embarking on regional studies of rabbit population ecology.

(ii) *Rabbit Biology and Behaviour*

Study of an experimental population at Gungahlin was continued. Earlier information on territorialism, the higher reproduction and survival rates of dominant individuals, and intrauterine mortality was confirmed and extended. The role of the superficial submandibular gland (present in both sexes, but fully developed and active only in males) in territorial marking was studied. Injection of male hormones into females can stimulate secretion by the gland and increase the urge to mark by means of "chinning".

There was a population crash, due to food shortage, in April. Only 40 rabbits (mostly dominant individuals) out of 140 survived. Mortality was heaviest among young animals.

In the experimental population at Albury, after heavy mortality in the original three enclosures (due to seasonal losses, plus a myxomatosis epizootic), only 21 animals remained at the end of the 1958–59 summer. They were placed in one enclosure and observed for another year, during which 240 kittens were produced. A further series of mass deaths, primarily from starvation due to depleted pastures, reduced the population to six by the end of the 1959–60 summer, and the experiment was then wound up.

The possibility of an oestrous cycle of 7 days was studied by sectioning ovaries and subsequent examination of follicles; results are not yet complete. A study of effects of climate and food on the summer anoestrum is in progress.

(iii) *Physiology and Parasitology*

A method, practical with respect to time taken and reality of values determined, has been developed for ascertaining the relative nutritive values of foods eaten by rabbits in the field. Rabbits are shot during their active grazing period (8–11 p.m.), when soft pellets in the stomach are at a minimum. Samples of freshly ingested food are taken and stored in formalin for subsequent analysis. Use of nitrogen content as an index reveals a monthly variation in the value of food selected.

Analysis of haematological data collected in the Gungahlin enclosure over two years showed no variation from the normal physiological range, even in severe conditions of population density and food shortage. This indicates the high adaptability of the rabbit to adverse conditions.

(1) *Findings regarding Physiology of Digestion.*—The fundus of the stomach of the rabbit is analogous with the rumens of sheep and cattle in that it is a region of the stomach, maintained at relatively high pH, capable of breaking down carbohydrates of high molecular weight by microbial activity. The microbial flora of the fundus is renewed daily by ingestion of live bacteria in the soft pellets. Soft pellets are morphological entities consisting of a tough slippery membrane enclosing a collection of bacteria and undigested cellulose. The pellets also contain a large amount of inorganic phosphate that buffers in the region pH 4–7, so that a relatively high pH can be maintained in spite of secretion of hydrochloric acid by the fundus. The bacteria of the pellets can glycolyse starch and the end-product is lactic acid. This glycolysis, by the bacteria or by homogenates of the pellets, is inhibited by a decrease in pH; hence the buffers in the intact pellet are necessary for fermentation of starch.

(2) *Parasitology.*—The first stage in the study of the epidemiology of coccidiosis (*Eimeria* spp.) in the Gungahlin experimental population has been

completed. Contrary to expectations and earlier reports, coccidiosis was not a primary factor inducing mortality among kittens or adults. Severe infections with *Eimeria* spp., however, suppressed the weight of adults and checked the growth rate of kittens. Average rate of infestation with coccidia rose with increase in density of population. Dominant individuals and their progeny were found to be more resistant to coccidiosis.

(iv) *Control*

The bait-preference study is almost complete. Carrot was found to be acceptable all the year round, but oats failed as a bait in hot dry weather. There was no sex differentiation in preference, except that breeding females showed less discrimination than other rabbits. Rabbits less than 3 months old accepted oats less readily than older animals. Laboratory experiments at Gungahlin indicated that the current field strength of "1080" for carrots could be halved, but that the strength of "1080" as now used with oats is about optimal. Experiments in 4-acre enclosures at Albury confirmed that the concentration of "1080" with carrots could be reduced to 0.01% without loss of efficiency.

An experiment with a poison trail in an enclosure at Albury, where social grouping and territorial boundaries were known, confirmed the need to place the bait within each territory for the most successful kill. Better kills from broadcast poisoning can be obtained in late summer before the "autumn break", when territorialism is at a minimum; chances of kitten survival are thus reduced. Aerial broadcasting of poisoned baits is being further studied at Albury and at Canberra.

In December a field trial of aerial poisoning was carried out in cooperation with a commercial firm. Results showed that the pieces of bait were too large and the bait-cutter was inadequate; that the pilot misjudged the extent of spread; and that "complete saturation" was a fiction. Marking to increase pilot-accuracy was technically and economically impracticable. The Engineering Section is now trying to improve bait-cutter design and to find dispersing equipment that will increase the swath width.

The proved efficacy of lower "1080" concentrations prompted a study on sublethal doses. Resistance of individual rabbits to "1080" injected intravenously at 24-hr intervals varied greatly; the effect was cumulative, and the minimum lethal dosage was 0.15 mg/kg daily for 5 days.

Studies began on development of bait shyness with use of "1080", and on rabbit foraging behaviour in relation to broadcast baiting.

New Poisons.—The compound 1-fluoroglucose, synthesized in the Chemical Research Laboratories, was found to be non-toxic. Fluoroleic acid, alleged to be the active ingredient in ground-up seeds of *Dichapetalum toxicarium*, is a humane poison for the rabbit since death occurs after what is apparently a single heart attack. The substance was found to be very toxic to sheep.

Cooperation with the Leichhardt Rabbit Board (Qld.) in the reorganization of rabbit control strategy in its district, and in the introduction of new control techniques (particularly use of "1080") continued.

In New South Wales the Section has maintained its interest in rabbit control through the State's Rabbit Control Advisory Committee.

(*b*) *Kangaroo Investigations*

Analysis of data from tagged animals suggested that some euros (*Macropus robustus*) can live without access to free water. This was supported by location of a sparse desert population of euros between Marble Bar and Broome, W.A. These animals must depend on dew and plant juices, apart from occasional rain; caves are available as refuges from heat.

A sample of 100 euros was trapped at Woodstock to measure changes in age structure of the population. Recapture of marked animals provided data for age–growth studies.

At Talga Talga station 12,000 euros were poisoned in 2 months by following C.S.I.R.O. recommendations, and an area of 120,000 acres had been almost cleared of the animals.

In August and November 1959 and February 1960, 500 female euros were shot to obtain reproductive data. Breeding in the Marble Bar area had almost ceased by the summer of 1959 because of drought. Cyclonic rains early in 1960 renewed breeding, with a high survival rate. Subsequent rains have ensured a one-third increase in euro numbers in 1960.

In western New South Wales, mainly near Hay and Wilcannia, a study has begun of the red kangaroo (*Macropus rufus*) — its food habits, breeding, and movements. Regular collection of samples and a system of air surveys have been instituted. Trapping and marking of the animals have been undertaken on a small scale.

(*c*) *Dingo Investigations*

A survey of the dingo (*Canis familiaris dingo*) problem in north-eastern New South Wales has been practically completed. Damage on 400 properties was assessed. Dingo damage occurred mostly in sheep flocks adjacent to rough country used for cattle-raising or forestry. About 3000 dingoes are killed annually in the area surveyed.

The effectiveness of present control strategy (based on scalp bounties) and current control techniques (including aerial baiting) are being investigated. As sight counts are inadequate for census taking the dingo population, studies of seasonal variation in dingo activities are being made from such signs as footprints, scratches, and droppings.

(*d*) *Fox Investigations*

Collection of samples with reference to food habits and breeding cycles of the fox (*Vulpes vulpes*) was completed, and data are being analysed.

(*e*) *Other Mammal Investigations*

Work continues on browsing marsupials in the Australian Newsprint Mills concession area of central southern Tasmania. The animals involved are the brush possum (*Trichosurus vulpecula*), the scrub wallaby (*Thylogale billardieri*), and

Bennett's wallaby (*Protemnodon rufogrisea*). Local control measures, using pollard–bran baits and "1080" poison, have been effective for all three species.

Two burnt areas are being studied to clarify plant–animal relationships. On one of these areas marked animal populations are being left undisturbed, as a control for the poisoned cut-over. Indications are that the culprit species can be removed from some coupes with benefit to the reafforestation program, but a satisfactory dense stocking of seedling eucalypts must be achieved before poisoning takes place. Burnt areas quickly produce weed growth that makes regeneration treatments difficult, especially if browsing animals are removed.

The subject of damage to regenerating or recently planted forest trees on the mainland by a wide variety of mammal species is being investigated.

Wombat (*Phascolomys mitchellii*) studies commenced. Some populations have been located, and specimens are being collected for investigation of breeding cycles and general biology.

A special committee examining possible reasons for the breakdown of an expensive and well-planned cattle-tick–eradication campaign in the Kyogle-Bonalbo area (N.S.W.) has requested that the Section investigate the possibility that native fauna might act as casual alternative hosts to the tick. A rapid survey of the area was made to determine which native species were associated with cattle. Later about 60 members of suspect species (all wallabies) were collected in a tick-infested region of southern Queensland. Two of them (one each of two species) harboured larval ticks, only one of the larvae being attached; no engorged females were seen. The project, which requires much further work, is continuing.

Preparation of results of the phase of the Antarctic elephant seal study that ended in 1959 is well advanced. Records of survival of branded seals during the period 1951–59, and study of behaviour of animals of known age and sex, are providing necessary basic data for long-term commercial sealing operations.

3. Bird Investigations

(*a*) *Wild Duck Investigations*

The wild duck studies have now been completed. A comprehensive report in four sections — Habitats, Movements, Food Habits, and Breeding — was published in *C.S.I.R.O. Wildlife Research* in December 1959.

(*b*) *Mutton-Bird Investigations*

Studies of the biology of the Tasmanian mutton-bird (*Puffinus tenuirostris*) were continued in cooperation with the Tasmanian Fauna Board. As formerly, basic work was done on the Furneaux Group of Islands. Over 5000 birds were banded in 1959–60, bringing the total to over 30,000.

One yearling was recovered off Japan in July and another, evidently returning from the northern migration, in New Zealand in December. A total of eight banded birds — all immature — have been recovered so far in the North Pacific. Another banded bird, 6 years old, was picked up on the beach at Shellharbour, N.S.W., in December.

The first New South Wales breeding site of the species was discovered on Tollgates Islands last year, but in 1959–60 several other breeding sites have been found in the State. It is not yet known whether these were new, or merely previously unreported, colonizations.

Although the birds are normally tenacious of nest sites, some evidence of inter-island movement has been observed and is being studied.

A survey of mutton-bird and magpie parasites and diseases continued in cooperation with the Department of Bacteriology of the University of Melbourne.

(*c*) *Magpie Investigations*

Comparative studies of seasonal gonad development in magpies (*Gymnorhina tibicen*) in the Australian Capital Territory show that adequacy of environment (including intraspecific relationships) causes gonads to respond earlier and attain greater size. Testes mature in all situations, but the ovary does not enter the final rapid phase, which coincides with nest-building, unless the required complex of proximate stimuli is present. Strong social dominance within the territorial group does not prevent subordinate females from attempting to nest even when no suitable nest-site is available, nor does it affect teamwork in boundary disputes. A field experiment with caged intruders showed that hens, but not cocks, suffer a psychosomatic response to a stranger that they cannot dominate; the ovary regresses and nest-building ceases abruptly. Seasonal vitality and possible malnutrition in territorial and flock birds are being studied by food analysis and by blood tests for haemoglobin and sugar.

(*d*) *Emu Investigations*

Movement patterns of emus (*Dromaius novae-hollandiae*) are being studied in pastoral areas of Western Australia. Attention is being concentrated on the land and weather systems south of the Gascoyne-Ashburton Divide and west of Lake Carnegie, especially with regard to food and water supplies, movements of the birds, and timing of the breeding season.

(*e*) *Tasmanian Native Hen Investigations*

Investigation of the native hen (*Tribonyx mortierii*) in Tasmania began with the appointment of a new officer in September 1959, in cooperation with the Animal Health Service of the Tasmanian Department of Agriculture. Habitats in the midlands and north of the island have been surveyed, and areas selected for periodic observations of population density. Food, movements, behaviour, and breeding are being studied, as well as damage to crops and pastures.

(*f*) *Other Bird Investigations*

Studies of raven (*Corvus coronoides*) trapping were continued. An extensive field trial with 25 traps, and study of ravens' reactions to various trapping techniques, suggest that inconsistency and poor results of trapping stem from behavioural factors in the birds, which might be difficult to demonstrate. No standard trap was crow-proof.

The general biology of black cockatoos (*Calyptorhynchus* spp.) in southern Western Australia is being studied, with a view to possible control measures. A team of amateur observers is cooperating with Section officers in recording movement patterns. Food and breeding requirements are also receiving attention.

A reconnaissance of blackbird damage to fruits in Tasmania has been made.

Laboratory studies on factors controlling the breeding cycle of the zebra finch (*Taeniopygia castanotis*) in Western Australia were continued. Further experimental work was also done in Western Australia on the migratory waders or shore-birds, which breed in northern Asia.

Field work for the Macquarie Island bird report is being completed in 1960.

(*g*) *Bird-Banding Scheme*

The number of banders was increased to 125 during 1959–60 and over 30,000 new birds were banded, bringing the total number to approximately 134,000.

Mr. H. J. Frith succeeded Dr. R. Carrick as Officer-in-Charge of the Scheme in April 1960. Mr. R. H. Green was appointed Regional Organizer for Tasmania, and Dr. C. O. Fuller succeeded Dr. A. H. Lendon as Organizer for South Australia.

Arrangements have been completed for the introduction of the Hollerith punch-card system to operate as from July 1, 1960.

13

Division of Land Research and Regional Survey

1. General

The Division of Land Research and Regional Survey undertakes land research designed to survey the potentialities and define problems restricting further development of regions in Australia and New Guinea. In the past, the pattern of development of Australian rural production, like many other industries, took place in a haphazard and uncoordinated way. As a result rural settlement was concentrated often in areas where accessibility was the dominant factor, little thought being given to the relative importance of physical resources inherent in other regions. Within the post-war period there has been a more logical approach to rural development, and a scientific assessment of land potential has been considered a necessary preliminary to development.

The Division of Land Research and Regional Survey has its headquarters in Canberra, and field stations at Alice Springs, at Katherine, and near Darwin in the Northern Territory, and in the Kimberley region, Western Australia.

The Division has worked mainly in underdeveloped areas of dry monsoon zones of the far north, the arid interior, and the Territory of Papua–New Guinea. Paucity of information on some of these regions has stimulated the Division to supplement its surveys by initiating agricultural research work at Katherine, Alice Springs, and Darwin in the Northern Territory, and in the Kimberleys of Western Australia.

More recently, however, the Division has extended its work to areas which are more agriculturally developed. For example, the Division is cooperating with the Hunter Valley Research Foundation in a land survey of the Hunter River catchments, and requests for survey work have been received from a number of other agencies. Cooperation is also maintained with the Division of Meteorological Physics, the Western Australian Government, the universities, and the Bureau of Mineral Resources and the Division of National Mapping of the Commonwealth Department of National Development.

In addition to the work of the Division of Land Research and Regional Survey much research is being carried out by other C.S.I.R.O. Divisions and Sections on development of low-producing areas in less isolated regions. The

Division of Biochemistry and General Nutrition is investigating problems of plant and animal nutrition on the Coonalpyn Downs in South Australia (*see* Chapter 10); the Division of Animal Genetics is breeding cattle at "Belmont", Rockhampton, Qld., with the object of developing animals suited to our northern environment (*see* Chapter 7); the Division of Tropical Pastures is studying problems of increasing productivity in many parts of Queensland, including wallum and brigalow country (*see* Chapter 4); and the Division of Soils is making soil surveys throughout the Commonwealth (*see* Chapter 2). Allied work is also carried out by the Division of Plant Industry on plant and pasture ecology (*see* Chapter 3).

The Agricultural Research Liaison Section is participating in the cooperative study of the Southern Tablelands to assess existing and potential agricultural resources of this region (*see* Chapter 17).

The major administrative change in the Division of Land Research and Regional Survey during the year was the resignation of the Chief, Mr. C. S. Christian, who was appointed to the Executive of C.S.I.R.O. Mr. G. A. Stewart was appointed Acting Chief of the Division pending a permanent appointment.

The Kimberley Research Station Policy Committee recommended to the Commonwealth and Western Australian Governments that joint funds used to operate this Station should be increased to allow expansion of the work. Both Governments agreed to this request and the annual operational vote for the Station has been raised to £92,000 per year for the next five years.

2. Regional Surveys

The work of regional surveys on the mainland of Australia has been expanded during the year with the formation of a second land survey team. As a result a survey of the Hunter Valley has begun. The Papua–New Guinea team established in 1953 has continued to work at the request of the Department of Territories.

(*a*) *Australian Mainland Survey Unit*

(1) *West Kimberley Survey.*—Field work in this area (47,000 sq. miles) was begun as a result of an urgent request from the Western Australian Government, and was completed between July and October 1959. Officers of the North-Western Division of the Department of Agriculture cooperated in the project. Final photo-interpretation has been completed and preparation of the report and maps is in progress.

The area lies within the influence of the monsoons which provide a short period of summer rainfall with a long period of annual drought. Much of the country to the north and north-west, vegetated by grassy woodlands of various eucalypts and soft spinifex, is mainly rugged massive quartzite country with small, more fertile valleys of volcanic soils. To the south of the King Leopold Range the trees become more sparse and the country is dominated by spinifex, except for the broad black-soil plains of the limestone country and the extensive flood-plains of the major river systems on which are found the better pasture types. To the west extensive sandplains with dune fields supports a scrubby eucalypt-spinifex association known as Pindan.

Cattle and sheep are the principal forms of land use and the distribution of these still reflects the pattern of original settlement. Sheep occupy only the central portion of the area west of Fitzroy Crossing and to the north of and along the Fitzroy River. Over-stocking and mismanagement have produced widespread pasture degradation and resulted in a gradually decreasing carrying capacity throughout the country.

Because of the shortness of the growing season, dryland farming would be hazardous. Closer settlement schemes must be based on the irrigation of parts of the main river flood-plains or associated black-soil areas.

Rice has been grown successfully at Liveringa by a private company and it is hoped that this enterprise can be expanded in the future.

(2) *Hunter Valley Survey*.—There are two main reasons why this area differs from those previously surveyed by the Division — it is relatively small (about 9000 sq. miles) and it has been occupied by Europeans since the early days of settlement. It comprises the catchment of the Hunter River and its tributaries.

Field work, which is now nearly complete, has alternated with periods of office work during which the mapping and description of the country have been started.

Land forms of the Hunter Valley show a close relationship to the geology. In the south are rugged sandstone hills, while to the north and north-west are undulating plateaux and steep ranges developed on basalt. Rugged country occurs on hard lavas, sandstones, and conglomerates in the north-east, while in the centre of the Valley is a belt of lower country formed of softer sandstones and shales. Towards the coast is an area of swamps and sand dunes developed in geologically recent time.

Rainfall over about half the valley is between 22 and 30 in. a year. Over approximately a quarter of the valley it is below this; and over the remainder, mostly in the east, it is higher, rising in places to 60 in.

Soil development follows the trend of rainfall; in low rainfall parts soils with alkaline horizons are common but in higher rainfall parts the soils are characteristically more strongly leached and are acid throughout the profile. This trend is also reflected in the degree of development of the alluvial chernozems. Basalt has been dominant in giving rise to fertile cracking clays near Merriwa.

In the relatively inaccessible parts of the region the vegetation is mainly eucalypt woodland except for some rain-forest in the high and wet Barrington Tops area. In the more accessible parts the vegetation has been changed greatly by the clearing of the original woodland and the destruction of many of its grasses. Grazing over most of the non-arable country is uncontrolled and production is far lower than it could be.

The survey will combine information collected during field work into an account of the Valley's potential.

(*b*) *Papua–New Guinea Survey Unit*

The Wewak–Lower Sepik area (4600 sq. miles) was surveyed in July–October 1959. This area was selected by the Administration of the Territory of Papua and New Guinea, because of the serious threat of over-population in large hilly areas, and to investigate the possibilities of bringing into use vast areas of rather flat grassland and low lying swamps.

The area comprises about 600 sq. miles of rugged mountainous country, generally below 3000 ft altitude and largely covered by rain-forest on brown forest soils; some 1000 sq. miles of hilly country mostly under forest, but with extensive areas of garden regrowth and grassland, and with soils ranging from brown forest soils to meadow soils; 1050 sq. miles of level to rolling grass plains with meadow soils and meadow podzolic soils; 450 sq. miles of alluvial clay plains which are partly flooded each year and covered mostly with forest; and 1500 sq. miles of grass, sago, forest, and mangrove swamps, with alluvial heavy clays and peat soils.

Profitable immediate development seems to be possible only in parts of the alluvial plains. On the grassland plains the very low fertility and very poor physical properties of the soils will require much further research. Grazing and cultivation are further complicated in many places by uneven microrelief. Prospects of reclaiming swamp land are very remote, because of severe annual flooding. The physically poor soils would moreover be suitable for only a very limited range of crops.

3. Geomorphology

The Geomorphology Unit has been concerned primarily with regional surveys and research arising from them. In the Kimberley region, close attention was given to flood-plain morphology in relation to irrigation, and detailed levels were correlated with soils, vegetation, and air-photo patterns. In the Hunter Valley, lithological control of land forms and soils, and relationships of colluvial aprons and alluvial terraces were studied. These relationships should apply to much of the Central Highlands of New South Wales. In the lower Sepik Valley of New Guinea the interplay of tectonics, erosion, and deposition are being studied as a key to the land system pattern, and land potential of the region.

Other studies, in part arising from regional surveys, include: dune patterns, profiles, and sand grading in part of the Simpson Desert, general correlation between land forms and soils in the Avon Valley of Western Australia, and microrelief in the Sepik plains. A report has been completed on the Yass catchment, dealing with the genesis of cyclic land forms as a background to land studies in the Southern Tablelands.

4. Systematic Botany

During land surveys, botanical specimens are collected and identifications made by the staff of the Divisional herbarium. Over 700 determinations of specimens collected during surveys on the Australian mainland were made and 6120 duplicate specimens were sent to herbaria in Australia and overseas.

A descriptive account of the pasture types of the West Kimberley region has been prepared and a systematic and geographic account of the flora of central Australia has been completed.

Systematic work on plants collected during the Papua–New Guinea surveys poses difficult problems as descriptive literature is scattered widely and facilities for routine identification are virtually non-existent. During the year scientific papers on five genera from Papua–New Guinea have been prepared. Some 3800 specimens were added to the Divisional herbarium from Papua–New Guinea and 922 duplicate specimens were distributed to overseas herbaria.

5. Climatology

In most undeveloped regions of Australia climatic factors are of primary importance in limiting development and productivity. The Climatology Unit studies climate relationships to define and interpret the elements of climate which affect plant growth and production.

During the past year the comprehensive field experiments have been completed which were conducted on the two major arid zone vegetation communities, spinifex (*Triodia basedowii*) and mulga (*Acacia aneura*) for the past three years.

These studies had the specific objective of evaluating the soil water balance and heat balance of the communities and of studying within the framework so provided, the physical environment in which the plants existed, and the physiological responses of the plants themselves.

The measurements made included (i) incoming water, as direct rainfall and rainfall which was intercepted by the plant canopies and channelled down the stems, (ii) surface run-off and infiltration characteristics of the soils, (iii) outgoing water, as change in soil water storage, by using the neutron dispersion technique in addition to conductivity methods and direct gravimetric soil sampling, (iv) total incoming radiation and diffuse sky radiation, (v) net radiation, and soil heat flow at different plant-soil surfaces, (vi) profiles of soil temperature, and atmosphere temperature, humidity, and wind speed at different points in the communities, (vii) plant growth in terms of shoot elongation and leaf and phyllode shedding, (viii) plant-water relationships in terms of relative leaf water content, water potential of the leaf tissue, and osmotic potential of tissue cell sap.

The experiments have therefore provided a quantitative description of the physical environment in which the plants live and of the responses of the plants within this environment. This information is of immediate value in planning more efficient utilization of the communities for grazing by domestic animals and also provides a firm basis for the objective planning of subsequent agronomic experiments.

Laboratory studies have continued into methods of measuring water content and water potential of leaf tissue. Present techniques are accurate but time consuming, and involve tissue destruction. A promising method of leaf water-content measurement, involving determination of changes of electrical capacity, is at present being investigated. Should the technique be successful it would not only be rapid but would also involve no tissue damage, thereby enabling repeated measurements to be made on one leaf. Investigations of water-potential measurement techniques are also proceeding, and modern hygrometric methods using sensitive wet bulb equipment, electrolytic condensation hygrometry, and application of the Peltier effect are being examined.

Statistical examinations of climatic data to provide detailed climatic information to the survey and research station groups in the Division have been continued. Studies of climate in survey areas in New Guinea, and in central and Western Australia, have been completed. A re-examination of the Katherine climate has also been completed incorporating as much data as possible from cropping records.

6. Hydrology

The hydrological investigation of the Wiluna–Meekatharra area started last year has been completed. Work in the Hunter Valley has begun with the installation of crest gauges in small catchments, to differentiate the run-off characteristics of different land systems. For streams in alluvial country an attempt is being made by indirect methods to estimate flows when the water is at the top of the bank, and its relation to frequency of flooding and type of catchment. Existing stream flow records are being analysed to determine general rainfall -run-off relations, and the contribution of groundwork in reducing flood peaks and mitigating droughts.

A theory has been developed for flood discharge estimation from water-level records only, and a test project involving the use of two long-term recorders is to be set up in the Wollombi Brook catchment of the Hunter Valley as soon as instruments are available.

Processing of hydrological data presents as much a difficulty as their collection, and while there is a great deal of data available at the Meteorological Bureau and with the stream gauging authorities, manipulation by standard techniques is necessary to produce the type of information required. These techniques are amenable to programming for automatic calculation by high speed digital computers, and this field is being studied. Investigations are also being made to extend the usefulness of the long-term recorder by using its punched hole record for automatic production of data tapes.

7. Agricultural Ecology

Further progress has been made on compilation and evaluation of existing technical data relating to the Ord Irrigation Project. Although review of the data is not yet completed, the study has served as a basis for answering some urgent enquiries in connexion with the first stage of the project now being implemented by the Western Australian authorities. It has also served as a basis for planning an expanded research program at the Kimberley Research Station.

A preliminary review of the practical implications of the research findings at the Katherine Research Station was prepared at the request of the committee to enquire into the prospects of agriculture in the Northern Territory. This review indicated that a mixed farming system involving production of peanuts as a cash crop and fattening of purchased store cattle on native and sown pastures, fodder crops, and peanut cake and residues offers more advantages than either a purely arable farming system with peanuts and sorghum as cash crops, or a purely pastoral system with fattening of stores on native and sown pastures.

As the result of a further request from the same committee, the possibilities of utilizing underground water in central Australia for irrigation were examined. From preliminary estimates of the quantity of water available and of crop water requirements, it appears that an area of the order of 10,000 acres could be brought under irrigation. An investigation was made of the possibilities of growing fodder crops for the local pastoral industry as well as cash crops for the southern Australian markets and for export. In addition to the good quality water, there is in the area a considerable quantity of saline water which could be used for salt-tolerant crops such as date palms.

Possibilities of expanding cotton growing in Australia were reviewed. The general conclusion reached was that although some Australian environments are sufficiently similar to those of recognized cotton growing areas to justify investigation of their potential, they are sufficiently different to require a specific variety-method complex.

8. Katherine Research Station

The crop research program has been devoted largely to the agronomy of peanuts, cotton, and grain sorghum and their place in farming systems. In an attempt to widen the range of possible cash crops, sesame and castor bean are being tested on a field scale for the first time, and are showing promise.

The most important findings of the past season are:

(*a*) Maintenance of cotton and peanut performance on land that has been under these crops for 11 years in succession;

(*b*) confirmation of rock phosphate as a very efficient fertilizer with long-term residual effects;

(*c*) excellent performance of cotton for the second year in succession on a newly examined red sandy soil;

(*d*) indication that peanut yields can be increased with closer spacing and higher plant populations;

(*e*) high grain yields obtainable from hybrid sorghum introductions.

The aim of pasture, fodder crop, and cattle research is to develop systems of beef cattle fattening for the region, not only with native sown pastures but also in association with arable farming systems.

The most important findings of the past season are:

(*a*) Establishment of a management pattern for *Cenchrus*–Townsville lucerne pastures and demonstration that the presence of the legume in a mixture is equivalent to at least 4 cwt per acre per year of nitrogen fertilizer;

(*b*) demonstration of the ability of the fodder crop bulrush millet to take up available nitrogen that has been leached out of the root range of other crops;

(*c*) confirmation of the previous season's results on intensive cattle fattening, showing that store cattle can be fattened during the dry season on local products at gain rates of over 2 lb per day;

(*d*) confirmation of the previous season's results on the value of small quantities of protein supplement to cattle grazing native pasture in the dry season.

Primary investigations on the availability of soil nitrogen under arable cropping and sown pasture are being completed.

Climatic extremes, viz. long dry and wet periods, determine the rate of initial formation of nitrogen and its location in the soil profile. This results in maximum availability at the onset of the wet season and stresses the importance of early sowing. With late-sown crops, nitrogen can be temporarily immobilized by incorporation of plant residues. Quantitative studies of input of nitrogen by legume crops and removal of nitrogen by non-legume crops have commenced recently.

9. Kimberley Research Station

This Station, which is operated jointly with the Western Australian Department of Agriculture, continued its work with irrigated crops.

The year was a rewarding one as the Western Australian Government decided to press forward with the development of commercial irrigated farming in the Ord Valley, on the basis of research work previously carried out at the Station. Crops recommended so far for planting on the first farms to be established are rice and safflower.

(1) *Rice*.—The research program was restricted this year to enable bulk crops to be grown for seed for the first commercial planting in the 1960–61 wet season. Further selections of 146 lines from 21 crosses were made with a view to developing improved varieties for the region. In conjunction with work at the Station, studies under controlled conditions are being made at Canberra on certain factors affecting growth of rice. The relative proportion of grain and straw is controlled both by nutritional factors and duration of growth. Concentration of nutrients in grain and straw appear to be correlated. It may be possible to develop from analysis of mature plants a method of diagnosing factors (such as nitrogen deficiency) which have limited yield.

(2) *Oil Crops*.—Studies on oil seeds have been concentrated on safflower, linseed, castor bean, soybean, and sesame. It was confirmed that high yields can

be achieved by using agronomic techniques already developed, but insect attack reduced the amount of seed harvested. A research program was begun to develop more efficient insect control measures in conjunction with the Western Australian Department of Agriculture.

In work under controlled conditions at Canberra the rate of development of safflower appears relatively unaffected over a wide temperature range, but at higher temperatures plants flower earlier and yield is reduced. Yield appears to be highly correlated with time of flowering.

With linseed it was shown that shallow plantings of about ½ in. depth resulted in the most satisfactory establishment. Work with four promising varieties planted at these dates showed that the Indian introduction RR 204 was outstanding.

(3) *Cotton*.—The promising results achieved in controlling insects in recent years has awakened interest in the suitability of cotton for the area. Yields of 2000 lb per acre of seed cotton were again achieved with the D.P.L. variety. Over 70 introductions were made as a preliminary step to breeding work aimed at higher yields and resistance to blackarm (*Xanthomonas malvacearum*).

(4) *Rain-fed Crops*.—Land survey of the Ord–Victoria region carried out by the Division has shown large areas of lighter-textured soils fringing the heavy-textured soils suited to irrigation. It appeared from experience at Katherine Research Station that these lighter soils might be used for rain-fed crops in the wet season. Preliminary trials were started with cotton, a number of oil seed and fodder crops, and a mixed pasture of Townsville lucerne and Birdwood grass. Sesame and cowpeas were successful, while peanuts after poor initial growth responded well to late rains.

10. Coastal Plains Research Station

From the results of the first year's work at this Station good yields can be obtained from drilled rice, provided irrigation water can be made available early in the season.

Puddling experiments in which pre-germinated rice seed has been broadcast on prepared mud either under water or exposed to the air have been successful.

Fertilizer experiments have shown spectacular responses to application of nitrogen and phosphorus. Interaction between the two elements is marked.

A rice breeding program has commenced to produce high quality rices with stiff straw suitable for mechanization.

Possible alternative crops for rotation with rice are being investigated. Dryland crops fail on the heavy black-soil plains during the wet season. Fodder crops that have a growing period between March and July are being investigated as alternative crops.

11. Arid Zone

Research in central Australia, based at Alice Springs, is devoted to ecological studies of the natural pastures, to increase their productivity. Three main lines of study are being pursued:

(*a*) Improved husbandry based on an ecological understanding of pastures and effects of grazing;

(*b*) improvement of natural pastures by seeding with more useful species;

(*c*) reclamation of degraded communities.

During the year particular attention has been paid to reseeding studies. These investigations have been divided into three closely related stages — species propagation and assessment in the field nursery; species adaptability and persistence in selected land units; and development of techniques of establishing promising species in areas of natural pasture.

In the first stage the number of new introductions has been increased substantially, 65 additional species or varieties having been introduced. Also, 45 persistence rows have been established with the most promising introductions. An assessment is being made of their performance under natural climatic conditions. About 20% of the introductions are shrubs and include a number of legumes; the remainder are grasses.

As a consequence of the difficulty involved in seedling establishment, experiments commenced to investigate the possibility of altering the microtopography in order to change the surface run-off at any one point. Preliminary results indicate that even on sandy soils water penetration under furrows spaced 5 m apart is more than twice as great as under an undisturbed surface.

14

Division of Fisheries and Oceanography

1. General

The Division of Fisheries and Oceanography is concerned with study of the aquatic resources of Australia. In recent years there has been a great increase in scientific investigation of the oceans and their resources. International cooperation has developed, especially in the prosecution of joint investigations, and all maritime countries of the world have expanded their oceanographical research programs.

The Division of Fisheries and Oceanography has been involved in this expansion and is cooperating with oceanographers of the New Zealand Oceanographic Institute and the Institute Français d'Océanie, New Caledonia, in a study of the Tasman and Coral Seas. Australia's expansion has been made possible because the Royal Australian Navy has provided ocean-going facilities in the Indian and Pacific Oceans.

The Division has its headquarters at Cronulla, N.S.W., laboratories in Perth and Melbourne, and field stations at Hobart, Thursday Island, and Eden.

During the year Dr. G. L. Kesteven was appointed Assistant Chief (Fisheries); Dr. Kesteven was formerly Chief, Fisheries Biology Branch, Fisheries Division, F.A.O., Rome.

Dr. Humphrey has been appointed a member of the Special Committee on Oceanic Research of the International Council of Scientific Unions, and convener of the Australian National Committee for Oceanic Research of the Australian Academy of Science. Mr. D. J. Rochford is also a member of this committee. Dr. G. L. Kesteven has been appointed C.S.I.R.O. representative on the Interdepartmental Advisory Committee on Fisheries Development.

The 14th School in Marine Biology was held at the laboratory in May 1960. Sixty-four students and members of staff attended from the Zoology and Biochemistry Departments of the Universities of Sydney, New South Wales, Queensland, Adelaide, Western Australia, and Tasmania. Lectures were given to senior students in zoology at the University of Sydney by Dr. J. M. Thomson and Dr. R. G. Chittleborough.

The Division gratefully acknowledges the assistance that it has received during the year from many quarters. The Royal Australian Navy has provided funds for research on marine fouling, and has made available facilities on four ships for oceanographical research. Thanks are expressed to the Royal Australian Air Force for the airlift of much heavy oceanographical equipment required aboard H.M.A.S. *Diamantina* operating from Fremantle, W.A. Financial assistance was received from the New South Wales Department of Fisheries for oyster research. The whaling research program was greatly assisted by the cooperation of the NorWest Whaling Company, Whale Products Limited, Byron Whaling Company, and Cheynes Beach Whaling Company. The Division is grateful to the many shipping companies and ships' officers who have regularly collected sea-water samples and dropped drift bottles from commercial ships.

2. Operations of Research Vessels

(i) *Cooperation with Royal Australian Navy*

(1) *H.M.A.S.* Diamantina.—Dm 1/59 Sydney to Fremantle. Gear testing cruise.

Dm 2/59 (October 11 to November 19, 1959). North-east Indian Ocean — Cocos and Christmas Islands. During this cruise 133 stations were worked. Of the 51 hydrology stations 19 were to less than 3000 m, 13 were to between 3000 and 4000 m, 16 to between 4000 and 5000 m, and 3 below 5000 m. Bathythermograms and surface samples were taken at 82 stations, 131 phytoplankton tows were taken, 29 Clarke Bumpus tows were made, and 49 samples were taken for CO_2 uptake and phytoplankton pigments.

Dm 1/60 (February 2 to March 23, 1960). Southern Indian Ocean. For some of this period the ship worked with R.V. *Vema* (Lamont Geological Observatory) on a seismic study. During the remainder of the cruise 114 stations were worked. At 56 stations samples were taken for hydrology; at 109, bathythermograms and surface samples were taken; at 27, CO_2 uptake, pigment, zooplankton, and phytoplankton samples were taken.

(2) *H.M.A.S.* Gascoyne.—G 1/60 (February 2 to March 8, 1960). Tasman and Coral Seas. Cyclones between Noumea and Sydney reduced the number of stations which had been planned. Eighty-eight stations were worked; 50 for hydrology, 82 for bathythermograms and surface samples, 21 for CO_2 uptake, pigments, and zooplankton, and 33 for phytoplankton.

G 2/60 (March 17 to April 21, 1960). Tasman and Coral Seas, including Port Moresby, Manus I., Kavieng, and Rabaul. One hundred and twelve stations were worked; 47 for hydrology, 86 for bathythermograms and surface samples, 36 for CO_2 uptake, pigments, and zooplankton, and 51 for phytoplankton; also 27 transparency readings and 10 bottom cores were taken.

(3) *H.M.A.S.* Kimbla.—(September 14 to 20, 1959.) N.S.W. coast. Eight stations were used to test the precision and sampling errors of the ^{14}C method of measuring CO_2 uptake.

(4) *H.M.A.S.* Warrego.—(November 9 to 19, 1960.) Lord Howe I. Diurnal variations in phytoplankton catches were examined at a single station.

The scientific results of these cruises are discussed under the relevant sections.

(ii) *F.R.V.* Derwent Hunter

This vessel has been engaged in longlining for tuna in south-east Australian waters in the area between 33 and 44°S. To determine the relation between distribution of tuna and water masses occurring in different seasons, water samples were collected at 126 stations, plankton hauls were made, and the tuna longline used at 47 fishing stations.

(iii) *F.R.V.* Marelda

This vessel continued monthly traverses from Eden, Bermagui, Bateman's Bay, and Jervis Bay taking water samples, surface current measurements, plankton hauls, and tagging the 592 tuna caught.

(iv) *F.R.V.* Thyrsites

This new barracouta vessel built in cooperation with the Interdepartmental Advisory Committee on Fisheries Development was launched in September. The first testing cruise was in April.

3. Oceanography

In the previous section of this report detail is given of cruises arranged in cooperation with the Royal Australian Navy.

(i) *Physics*

With the use of larger ships carrying out much more extensive cruises, automatic measuring instruments are required and several have been designed and built at this laboratory.

An inductive salinity meter has been tested at sea and gave an accuracy of ± 0.003 salinity units. Instruments to measure transparency of sea-water and intensity of submarine daylight to a depth of 200 m have been constructed and used at sea. A wave recorder has been designed and is to be installed and operated at Newcastle by the New South Wales Department of Works. A radiometer to measure surface temperature of the sea has been redesigned for use from a light aircraft.

Relation of sea-level (as monthly mean) to atmospheric pressure and water density has been examined with the use of data obtained as part of the IGY program. The high speed computer at the University of New South Wales is being used in a statistical analysis of daily mean sea-levels.

In the Coral and Solomon Seas measurements of transparency indicated that the layer below 100 m is extremely clear and that water at the surface down to between 50 and 80 m is only slightly turbid. Between these two layers a weakly developed turbidity layer only 5–10 m in thickness is usually found. Daylight decreases to roughly 1% of its surface intensity in depths of 90 to 110 m in the blue and green part and in depths of 15 m in the red part of the spectrum.

In study of the deep circulation of the Tasman and Coral Seas the deepest station occupied was in the Planet Trench where samples were taken down to 7750 m. It was found that contrary to previous belief bottom water of the Coral Sea Basin as well as that of the Solomon Trench is supplied from the East Australian Basin.

Theoretical studies on the influence of thermohaline circulation on general circulation in the oceans have been made. Different methods were used to assess magnitude and extent of thermohaline effects and it was shown that thermohaline circulation was less important than wind-driven circulation. A four-layer model of wind-driven and thermohaline circulations in a meridional plane has been constructed and found to be in agreement with the circulation pattern resulting from water mass analysis.

Transverse circulation of the Antarctic Circumpolar Current was calculated and various convergences and divergences appearing along the Antarctic Polar Front were explained in terms of variations of wind field.

(ii) *Hydrology*

(1) *Analytical Methods*.—Methods for the estimation of ammonia in sea-water have been investigated.

(2) *Oceanic*.—The seasonal succession of water types in the Coral and Tasman Seas was consistent from year to year on the 27.20 σ_t surface at about 1000 m, but at shallower levels, on the 26.80 σ_t surface, the succession was irregular and the northward flow of subtropical waters was very restricted.

Pulses of water, probably from the Banda Sea, occur at intermediate depths in a southward and eastward movement in the Indian Ocean. Assuming an annual formation of these pulses, a velocity of about 3–4 miles per day was calculated. This velocity agrees with direct measurements of intermediate circulation in the north Atlantic. The paths of the eastern branch carrying Antarctic waters northwards to the region south of Java and methods of mixing of these waters into the South-Equatorial Current were clarified by new data from recent cruises. On the 3000 m level, escapement paths of waters sinking from intermediate depths below the South-Equatorial Current were traced to the south-east. A relatively strong current was also detected west of Fremantle at 3000 m where this escapement path narrows considerably.

(3) *Coastal*.—This year the hydrological properties determined for coastal stations were comparable with those in 1942–43. A complete secular cycle may have occurred in this 18 years. During this period coastal temperatures are much lower in dry than in wet winters. These observations are being related to large-scale atmospheric changes associated with ocean circulation.

(4) *Eden Area*.—In the area of the east Australian tuna fishery, additional sections at Bateman's Bay and Jervis Bay were worked this year to delineate the configuration of the western edge of the East Australian Current. The boundary is irregular and meandering and warm high-salinity water moves in towards Bateman's Bay.

The southward summer advance of the East Australian Current was noted at 40°S. in October and about 43°S. in March. The Subtropical Convergence was shown to be a meandering boundary between sub-Antarctic water and the East Australian Current with intrusions of each with marked fronts of 1–2°C.

During this year the movement of the "Eden Coastal" water (a mixture of Indian Ocean water and sub-Antarctic water derived from the north-eastern region of Bass Strait) round Gabo Island and up the New South Wales coast, was found off Eden only during August. This year's occurrence was very small compared with that in 1958, when it dominated the shelf during July–September.

(iii) *Productivity*

Regular sampling of the Port Hacking section for CO_2 uptake and pigments by F.R.V. *Derwent Hunter* was terminated at the beginning of the year. A preliminary inspection of results obtained on the cruises by H.M.A. Ships *Diamantina* and *Gascoyne* shows that measurements of primary production in the Coral and Tasman Seas conform generally with those previously obtained from *Derwent Hunter* and from the Institut Français d'Océanie ship *Orsom III*. In the Indian Ocean a large area south of the equatorial stream shows considerable production at depths of 100 m with maximum production at 50 and 75 m. This is about 25 50 m deeper than that found in the Coral and Tasman Seas.

Statistical analyses of tests of precision and sampling errors in the ^{14}C method of measuring primary production show the method to be capable of measuring a production of 0.1 mg $C/hr/m^3$ with an accuracy of ± 0.02 mg $C/hr/m^3$.

A new method has been established to determine the zero-thickness activity of ^{14}C solutions used. This method gives an accuracy of ± 5% as compared with previous determinations by the barium carbonate precipitation method, which is about 20% lower.

Preliminary study of the relation between CO_2 uptake and chlorophyll pigment measurements indicates a poor correlation except under carefully selected conditions, e.g. samples taken from the same water mass at similar times of the daylight period.

(iv) *Zooplankton*

During the year zooplankton were collected at oceanic stations and at shelf stations, e.g. Port Hacking 50 and 100 m stations where weekly replicate hauls were made. Monthly hauls at 100 m were made at Jervis Bay, Bateman's Bay, Bermagui, and Eden, and at special shelf stations several hundred samples were collected throughout the water column over periods of 24 and 48 hr. Analysis of some shelf station collections suggests a pronounced seasonal succession of species correlated with changing environment.

(v) *Phytoplankton*

Rich phytoplankton growth was found in the New Guinea, New Britain, New Ireland, and Solomons region during a cruise in March–April 1960. Poorer growth could be noted farther south and in the Coral Sea. A definite diurnal variation has been found in the numbers of phytoplankton taken in surface hauls.

(vi) *Biochemistry*

Routine determinations of chlorophyll and carotenoid pigments from the 50 and 100 m stations off Port Hacking were continued during the 1959–60 period. Chromatographic identification of chlorophylls and carotenoids in algae from sea-water samples and from unialgal cultures was continued. Particular attention is now being given to xanthophyll identification.

Chlorophyll *c* has been isolated from bulk cultures of a marine diatom and a marine flagellate by paper and column chromatography. These preparations, though free from other pigments, were contaminated by variable quantities of neutral fat.

A new type of chlorophyll *a* has been found in several marine algae. The absorption properties of this pigment and its rate of formation in pure cultures are being investigated. Preliminary experiments on chloroplast isolation from *Isochrysis galbana* (a marine flagellate containing chlorophyll *c*) were made as a first step in a study of the function of chlorophyll *c*.

(vii) *Bacteriology*

Survey continued of changes in the populations of heterotrophic bacteria in waters off Port Hacking. Work is in progress to study the formation, function, and breakdown of some structural components of a Gram-negative marine bacterium. The stock culture collection has been enlarged and includes one organism which produces an antibiotic substance effective against Gram-negative marine bacteria.

(viii) *Benthos*

A preliminary qualitative survey was carried out on the continental shelf off Sydney. This survey has indicated several areas between the 50 and 100 m contours where dredging can be carried out on reasonably flat bottom.

4. Fisheries Biology

(i) *Whales*

A report on the Australian catches of humpback whales during 1959 was prepared for the 12th Meeting of the International Whaling Commission. The population of whales on the west coast of Australia has declined drastically from the low level reached in 1958, mortality rates of adults are greater than the rate of recruitment, and continued commercial whaling at the present level will reduce even further the residue of this population. The population on the east coast continues in a relatively sound condition although it has probably decreased slightly in recent years.

This season, with the help of a light aircraft spotting whales, marking was concentrated on lactating females, and 56 whales were marked. Twenty-one marks were recovered at Australian whaling stations in 1959, and of these five were fired by Russian scientists, and one by Japanese scientists, in the Antarctic. One Australian mark was recovered in New Zealand, and 11 in the Antarctic. From these recoveries, it appears that during the summer of 1958–59 the Group V (east coast of Australia) population had spread further westwards in the Antarctic than usual, and some mingled with the Group IV (west coast of Australia) population. Some of the Group V whales remained with the Group IV during the northwards migration of 1959, because two whales which had been marked in previous years off Moreton Island, Qld., were taken at Carnarvon, Western Australia.

One humpback whale, marked when a yearling in 1954, was recaptured in 1959; thus, its age at the time of killing was known. Ear plugs and baleen were collected from this whale and the estimate of age by these indirect methods was the same as the known age.

Twelve blue whales were taken off the west coast of Australia. Material and data collected from these indicate that they may be a stunted variety of the blue whale and that they may not migrate to Antarctic waters each summer. Several specimens were mature, though much shorter than the minimum legal length of 70 ft.

(ii) *Sea Fish*

(1) *Barracouta*.—The reading of otoliths has continued. Sea work commenced late in the year with the commissioning of the F.R.V. *Thyrsites*.

(2) *Tuna*.—F.R.V. *Marelda* based on Eden has been occupied with detailed study of the environment, study of sexually immature southern bluefin tuna which occur in surface waters, and tagging of tuna. F.R.V. *Derwent Hunter* was used to collect data on distribution of bluefin tuna at subsurface levels and on the environment in which they occur. Juveniles of the southern bluefin tuna occur in water of higher temperature and chlorinity than do adults.

Longlining operations carried out in areas where juveniles were observed failed to catch adults except in certain areas where oceanographic conditions brought colder water sufficiently near the surface for the longline to sample. Two types of tag were used this year; 464 fish were marked with a metal head and 128 with a plastic head and "Nylex" tube. From the former only one tag was recovered, but from the latter three were returned. Of the four recoveries, three showed local movements in a period of release ranging from 7 to 64 days and the other showed migration from eastern Australia to South Australia in 135 days.

(3) *Demersal Fish*.—Specimens of fish caught by the *Southern Endeavour* in the Great Australian Bight have been examined and 17 species were identified.

(iii) *Freshwater Fish*

Trout Investigations.—The report on the fishery of rivers of the southern part of the State has been completed and submitted for publication. There is good evidence of the existence of two, probably genetically distinct, races of *Salmo trutta* in Tasmanian waters, the result of separate introductions of river and sea trout.

(iv) *Crustacea and Shellfish*

(1) *Western Crayfish* (Panulirus longipes).—Analysis of the commercial catch of crayfish made in the Houtman Abrolhos area was continued. Study of relation

between carapace length and age groups suggests that the female breeding population consists chiefly of two age groups, the first with a mean length of 3.08 in. and the second, 3.45 in.

(2) *Southern Crayfish* (Jasus lalandii).—Eight hundred drift bottles were released making a total of 3900 since releases were commenced in September 1958; 33% of them have been recovered. These show an easterly surface drift through Bass Strait from September to November 1958, a westerly flow from November until February 1959, and an easterly set from March until September. There was then an abrupt change leading to a westerly flow in October and November with reversal to an easterly flow during December and January 1960. In February the flow changed to the west and persisted until April.

During Jannary 1960 at Cape Sorrel, Tasmania, 1324 undersized crayfish were punch marked with a series of five symbols each representing a centimetre range of length, the smallest from 7.0 to 7.9 cm and the largest from 11.0 to 11.6 cm. During this season 410 previously marked crayfish, in which the mark could definitely be recognized, were recovered at Port Sorell. Of these 314 had been free for 1 year, 94 for 2 years, and one for 3 years. These recoveries have given valuable information on growth rate.

(3) *Pearl Oysters* (Pinctada *spp.*).—The monthly sampling since 1956 of about 25 specimens of *Pinctada maxima* at three localities was terminated. No late spring spawning occurred in any area in 1958. The first spawning was delayed until January 1959.

Growth rate studies are being continued. Unfortunately tagging returns have been unsatisfactory because commercial operations have removed shell, even from closed areas. During a visit to Manihiki in the Cook Islands in April to June 1959 a survey was made of *Pinctada margaritifera*. A preliminary report was published and work on growth rate and gonad volume is continuing.

(v) *Taxonomy*

The second stage in the investigation of New Guinea fishes, the preparation of a handbook, has been continued. Four issues of the Handbook of Australian Fishes have been prepared.

(vi) *Marine Fouling*

Work was confined to larvae having direct development, i.e. the bryozoans *Bugula neritina* L. and *Watersipora cucullata* Busk. Settling reactions of these larvae to various types of copper and mercury antifouling paints were examined and concentration, mortality, and time relationships for copper, mercury, and zinc ions determined. Successful mass cultures of the diatom *Phaeodactylum tricornutum* Bohlin and the flagellates *Isochrysis galbana* Parke and *Dunaliella tertiolecta* Butcher have been obtained repeatedly from the mass culture unit and this will assist the rearing of larvae which have indirect development. As in previous years monthly counts were made on the kind and intensity of fouling at Garden Island, Sydney Harbour.

15

Fodder Conservation Section

1. General

The Fodder Conservation Section investigates the biochemical, physiological, and other changes associated with the conservation of fodder for livestock, and aims to develop improved techniques for the preservation of green fodder. Present-day practices in both haymaking and ensilage involve heavy losses. A more complete knowledge of the basic principles involved may lead to more efficient methods of conservation.

The headquarters of the Fodder Conservation Section is at Highett, Vic.

The Division of Protein Chemistry undertakes basic research of the biological degradation of cellulose (*see* Chapter 25). The Division of Entomology studies the insect pests of stored grain (*see* Chapter 11). The Engineering Section is studying wheat storage and is developing a mechanical silage loader (*see* Chapter 16). The Division of Plant Industry undertakes research on pasture management and supplementary feeding of livestock (*see* Chapter 3). The Division of Animal Physiology studies supplementary and drought feeding of livestock (*see* Chapter 9).

2. Chemical Composition of Fodders

The chemical composition of fodders provides a useful measure of their nutritive value. From the nature of changes in the composition of plants during the growing period, the best time for harvesting can be ascertained. Success of any conservation process itself may depend largely on the chemical composition of the material. Thus soluble carbohydrate content of herbage largely determines the course of fermentation during ensilage. Studies have been completed recently of the effect of maturity and light intensity on the chemical composition of ryegrass, particularly in regard to carbohydrate content.

Changes in composition brought about by conservation are being used to assess the efficiency of the various techniques being investigated. Efforts are being made to improve analytical techniques, and methods of extracting and evaluating the lipids in fodder are being critically examined.

3. Plant Physiology

(1) *Moisture Movement during Drying.*—Moisture movements in the leaves and stems of harvested pasture plants during drying are being studied. The higher initial moisture content and slower drying rate of petioles as compared with leaves of clover limits the rate of drying of such material. Increasing the rate of transference of moisture from petiole to leaf and using the leaf as an evaporating surface would increase the overall rate and uniformity of drying.

(2) *Respiration during Drying.*—Pasture plants respire for some time after they have been harvested and lose some of their more valuable nutrients. Factors affecting rate and duration of respiration are being studied. Measurements with Warburg respirometers have been paralleled by chemical analyses to determine the amount and composition of dry matter losses.

(3) *Susceptibility of Dry Pasture Plants to Mechanical Damage.*—Earlier investigations indicated that while susceptibility of hay to mechanical damage and shatter loss during field operations is affected to some extent by a number of growing and curing conditions, by far the most important factor is moisture content. Studies have now been made of susceptibility to damage of plants with a moisture distribution simulating that during actual field curing operations. Several strains of lucerne, white clover, and subterranean clover have been examined, and evidence obtained which suggests that overall susceptibility to damage differs between strains.

4. Plant Biochemistry

Protein breakdown in starving leaves represents one of the least desirable post-harvest changes associated with herbage conservation as either hay or silage. Studies are therefore being made of leaf protease and nitrogen metabolism in the more important pasture plants after harvesting. Variations are being examined between plant samples harvested on the one day and between samples of different maturities. Furthermore, as sap is a more convenient experimental material than intact leaves, comparisons have been made between leaves and sap expressed from them. Both leaf and sap systems of ryegrass reach equilibrium in regard to nitrogen distribution within 24 hr at 30°C. Each system at equilibrium retains 40-50% of its nitrogen as protein.

An attempt has been made to retard protein breakdown by treatment of the plant prior to harvesting with 2,4-D or maleic hydrazide, but with only very limited success.

5. Haymaking

(1) *Field Trials.*—The Division of Meteorological Physics has cooperated in experiments to determine the effect of various atmospheric conditions on the rate of moisture loss from curing hay. Apparatus developed by the Division has been used to establish profiles of wind speed, temperature, and humidity above swaths of hay, and to measure the radiant energy absorbed by the swaths.

(2) *Storage of Hay.*—Investigations have been completed of the effect of temperature and moisture on loss of dry matter and change in chemical composition during storage of hay. Dry matter losses increased with increase in both temperature and moisture and, in these particular investigations, reached a maximum of 9%. It has been concluded that the dry matter losses do not appear adequately to represent nutritional losses as appraised from changes in chemical composition.

Effects of light and absence of oxygen on changes during storage are also being examined.

6. Ensilage

(1) *Laboratory Trials.*—The major problems in making good silage are those associated with preservation of improved pastures and other high protein herbage. With such material ensiling losses are frequently high and the silage cannot be expected to keep for more than a few months owing to the small amount of lactic acid present. Special attention is therefore being given to ensiling high protein material, and trials this year included mixtures of ryegrass and clover in various proportions and lucerne. In the ryegrass-clover trials the important factors were carbohydrate supply, determined largely by maturity of the ryegrass, and moisture content. With ryegrass at the stage when the first heads had appeared, the addition of up to 40% clover had little adverse effect on the fermentation process, but with less mature ryegrass or higher proportions of clover the silage was of lower quality.

Trials have also been made to compare for ensiling material harvested by a forage harvester with that cut by a mower. Different types of pastures have been examined and also various makes of flail-type foragers (which cause differing degrees of laceration of the harvested material). Total dry matter, nitrogen losses, pH change, effluent production, and ease of consolidation are being studied. The main effect of laceration appears to be facilitation of consolidation. A method was devised for measuring the degree of laceration. Rates of drying under standard conditions have been found to give comparative values.

(2) *Microbiology.*—The most important bacteria in silage fermentation are those which produce lactic acid. Study of four representative strains of these bacteria to assess their ability to utilize carbohydrates and allied materials has provided useful data upon which to base methods for differential counts of mixed cultures.

Pure culture studies have also been made of the acid production of different types of lactic acid bacteria in ryegrass juice from material harvested at different maturities. The juice expressed from fresh and wilted ryegrass is being used and also that obtained by vacuum drying fresh juice and reconstituting it to various moisture contents. In wilting, except for a short period, there appear to be changes other than in moisture content, and these changes apparently affect bacterial activity. Measurements are being made of the water activity of the various juices to correlate moisture content with bacterial activity.

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Engineering Section

1. General

The Engineering Section carries out research and development in certain specific engineering fields, notably those of solar energy utilization, agricultural engineering, and environment control. It also undertakes development of special equipment for other Divisions and Sections of C.S.I.R.O., and provides technical advice and assistance to industry in fields of work in which it specializes.

Research in selected fields of engineering is also undertaken in various other C.S.I.R.O. Divisions and Sections, for example: the Divisions of the National Standards Laboratory study instrumentation and other problems in many fields of engineering; the Division of Forest Products studies the design of timber structures and engineering problems associated with timber utilization; the Division of Building Research and the Soil Mechanics Section study problems in the design of buildings and building foundations.

The Engineering Section continued to collaborate with the Division of Plant Industry, on the development of the Australian phytotron. Progress has been made with investigations into problems of wheat storage, under finance supplied by Wheat Research Funds. A new research program on tropical air conditioning has been initiated, in collaboration with the School of Public Health and Tropical Medicine in Sydney, and use is being examined of radiant cooling for this and other purposes.

Research continued in the Engineering Section on the use of solar energy, solar distillation, new materials for solar absorber construction, and protection of solar water heaters from damage by freezing.

Many requests were received from industry for technical advice and information, and while the majority of these could be answered directly or referred to appropriate authorities, others involved actual testing of products to assess performance or locate the cause of failures. Assistance was also given to industry by making available designs of instruments and equipment developed by the Section.

2. Phytotron

The phytotron project has now advanced to the stage where development of some of the naturally lit types of cabinet has been completed and preparatory arrangements have been made for their production in quantity by industry. The final emphasis of development has been on simplification and refinement of the basic designs, to reduce costs, and to increase operating convenience and reliability. This latter aspect has involved the development of special production techniques to ensure that refrigeration systems are clean internally and free from leaks, and also that they have an acceptably low free moisture content after having been charged with closely controlled quantities of refrigerant and oil.

Prototype cabinets to accommodate exceptionally tall plants have been built and are at present under test. These do not differ significantly, except in height, from the other naturally lit types.

Preliminary work has begun on the artificially lit cabinet design, using the high-intensity fluorescent tubes now available. Tests have been carried out to establish maximum light intensity obtainable at plant level, to study the effect on this intensity of variations in tube temperature, and to examine problems associated with maintenance of tubes at optimum temperature level.

Although the radiant energy which plants will receive in these cabinets is lower than full sunlight, this is compensated for by the uniformity of energy intensity. The uniform lighting conditions are also conducive to closer temperature control, so the artificially lit cabinets provide a higher-order controlled environment than the naturally lit units. The areas surrounding the latter cabinets in the temperature-controlled glass-houses are of a lower order again.

Lighting load in each artificially lit cabinet will be about 3.5 kW and the tube bank and the refrigeration condenser will be water-cooled. Heat removed from this group of cabinets provides a major source of energy for glass-house heating purposes. To distribute this heat each glass-house will contain one or more heat pump units, operating under automatic control to maintain constant ambient conditions.

Heat removed from all types of cabinet, whether by refrigeration or other means, will be conserved in a water storage and used as required. During summer months energy surpluses will accrue, and a forced evaporation system will be used to restrict the water temperature to a maximum value. In winter, the heat balance will involve lower storage temperatures, a recirculation system being used to keep condenser water supplies at approximately constant temperature.

Interesting problems arose in establishing the optimum size for water storage. This is a critical point in the phytotron design. An over-large pond would involve unnecessary expenditure, while satisfactory operation of the system under extreme conditions would be prejudiced if the capacity were too small.

Capital costs of a heat pump, heat storage system will increase with the size of the heat storage unit; running costs, on the other hand, will be reduced. For a given set of operating conditions, an economically optimum size exists. The system was simulated on an IBM 650 computer, using sampled meteorological data representing two years' conditions and evaluating running costs for four different sizes of heat storage unit at a time. The final design of heat storage was based on information supplied by the computer, which showed that the capacity required was appreciably less than that originally thought necessary.

3. Refrigeration System with Expansion Tube

Expansion tubes and thermal expansion valves are today the two most commonly used expansion devices in refrigeration systems. Advantages of the tube are simplicity, low cost, and absence of operational troubles.

The expansion tube is a constant bore and constant length tube, selected to expand the correct amount of refrigerant at design evaporator and condenser conditions. Once the length and diameter are chosen, no adjustment can be made for different heat source and sink conditions. This is regarded by the refrigeration industry as the chief disadvantage of the expansion tube, and it is qualitatively concluded that the tube is not suitable for systems in which design conditions are likely to vary. Its use is therefore limited almost exclusively to fractional horse power packaged systems mass produced to operate within a narrow range of conditions, as for example in household refrigeration. The extreme simplicity and low cost of the expansion tube are, however, compelling reasons for its application to larger plants and systems operating under variable external conditions.

It was therefore decided to study theoretically and experimentally the behaviour of a refrigeration system with expansion tube. The system was analysed as a loop, the links of which are influenced by the two external parameters, i.e. heat absorption and rejection conditions. The closing link is provided by the expansion tube which has to satisfy the condition of refrigeration flow continuity. The two-phase flow through the tube was expressed by a single formula, and the flow limiting sonic velocity plotted on a Freon 12 property diagram. Owing to the extensive computation required, the analysis is now being formulated in a manner suitable for an automatic computer.

4. Single Phase Electrode Humidifier

Development continued of this humidifier, which is a small low-pressure steam generator with two concentric electrodes, the outer of which forms the shell of the vessel. Experiment continues to find the most suitable materials and dimensions for stability of operation and high resistance to corrosion.

The most satisfactory results have been obtained with the outer electrode made of "Meehanite B" cast iron and the inner of stainless steel. During operation, the stainless steel electrode forms an oxide layer on its surface which performs two functions. Firstly, it protects the electrode from corrosion, and secondly, it increases surface resistivity beyond that of the water. Increases in salt concentration are reduced by a continuous flushing process, and such fluctuations as occur have little effect under these circumstances on the current drawn.

The outer electrode has a proportionally larger surface area, and the current density is therefore reduced correspondingly. After more than 6 months' testing on continuous on-off operation the electrodes did not show any appreciable signs of wear and current flow remained quite stable. It is, however, difficult to predict the long-term behaviour of the humidifier when water of different composition from the Melbourne supply is used. Long-term tests with the unit will be made in other parts of Australia to assess performance with various types of water.

A patent application has been lodged for the humidifier, and it is proposed to make the design available to manufacturers without restrictions.

5. Thermal Transducer

Basically the transducer is a copper or other tube with an electrical heater winding on one or both ends. Two other identical windings are symmetrically spaced about the tube centre and connected in adjacent arms of a balanced Wheatstone bridge circuit. All windings are electrically insulated from the tube but coupled to it thermally.

Electric power applied to either of the heaters will cause an unbalance of the bridge circuit. This unbalance, whether in the form of voltage or current, is related to the disturbing signal in a manner similar to those in a resistance-capacitance system, and can be applied to similar purposes.

Further applications of the device are now being studied, including its use as a circuit element for operations on low frequency signals. It is difficult to build passive electrical networks of low impedance and small size for the frequency region below one cycle per second. Thermal properties of materials, while imposing their own limitations, are attractive for this purpose, and it is hoped to operate with the transducer at frequencies less than one cycle per minute.

Fundamental relations and an approximate analysis of two units suitable for control system compensation have been published. A systematic approach to the problem of accurate synthesis and design of a versatile element capable of a high-order response is being carried out by means of a set of digital computer programs.

6. Temperature Controllers

Two on-off transistorized temperature controllers have been developed, initially for use in the phytotron project. The first of these is an uncompensated single-acting controller of medium accuracy, while the second is a double-acting unit with a thermal compensator to eliminate overshoot and a thermal integrator to reduce variations in the mean control level caused by the offset between heating and cooling. Both the compensator and integrator are adaptations of the thermal transducer, and have long time constants which would be difficult to realize electrically. This controller has proved successful in controlling temperatures to within close limits. Patent protection has been sought for both units, and a manufacturing licence has been given to a Sydney firm. Commercial production is at present at the prototype stage.

7. Oven Temperature Measurement

Equipment has been developed to measure the temperature of biscuits baking in a conveyor-type oven. Because of the oven construction this could not be done by conventional means without interfering with production. A miniature radio transmitter has been applied to measure the temperature and transmit a suitably modulated signal to a nearby fixed aerial. The transmitter, insulated to withstand the oven temperature, is placed on the conveyor band near the biscuit in which the sensing element is placed. The signal is then converted in the receiver to a temperature indication on a meter. As spark plugs fitted to the gas burners generate considerable interference it was necessary to develop special interference rejection circuits. Patent applications have been lodged in Australia and the United Kingdom, and several units are now being manufactured commercially under licence.

8. Transistor Applications

Many industrial applications of transistors have also been investigated. These include regulated power supplies, voltage inverters, phototransistor relays, proximity detectors, counters, and computing circuits. Patent applications have been applied for where these were warranted.

9. Wheat Storage

Heat transfer and moisture movement are being studied in stored wheat, to simulate the whole system of a bulk wheat storage using an electronic computer. The various factors are being investigated separately on a laboratory scale and the simulating system will then be tested with full-scale silo trials.

To investigate moisture movement under the influence of a moisture gradient alone, a specially developed capacitance-type hygrometer is used to follow moisture movement between adjacent bodies of wheat of uniform but different moisture content contained in a long tube. After one year redistribution of moisture is significant over a distance of only 1 ft.

Field observations have shown the desirability of equipment for making temperature and moisture measurements through as much of a wheat bulk as possible. For temperature measurements, cables have been constructed with nine thermocouple junctions at 2-ft intervals. The cables are inserted to depths of 20–30 ft or more using extendable steel rods. The thermocouple e.m.f. is measured with a standard potentiometer. For moisture measurements, a holder has been constructed for the recently developed anodized aluminium humidity-sensitive probe. The probe is inserted by using rods as for the thermocouple cable.

In investigation of the danger of phosphine fumigation, an estimate of natural air flow which can occur in a wheat bulk has indicated that this air flow must play an important part in bulk storage.

10. Disk Plough

The wheatland disk plough is being studied to provide data on the soil forces acting on plough disks and wheels. Two test rigs have recently been completed, one for measurement of disk forces and the other for that of wheel forces. In both cases the test component is on a sub-frame connected to the main frame by six links; the force in each link is indicated by a strain gauge load cell. Signals from the six load cells are transmitted to a 10-channel oscilloscope, and recorded by photographing the display on continuously running film. Oscilloscope, camera, and ancillary equipment are mounted in an instrument van running alongside the rig; the power supply for the equipment is in a trailer, towed by the van, so that the whole unit is independent of location.

The effect of a number of variables on the disk or wheel forces is being studied; those common to both disk and wheel are soil type, breast and undercut angles (usually referred to for a wheel as drift and camber angles), forward speed, and diameter. Additional factors to be considered are, for the disk: concavity, and furrow width and depth; and for the wheel: vertical load, type, pattern, and shape of tyre, and whether the wheel is intended to track in or out of the furrow.

Preliminary trials with the rigs have been held at Highett and full-scale field experiments are being made at the State Research Farm, Werribee, on red-brown clay loam. These comprise 192 treatments for disk studies and 128 treatments for wheel studies, on one nominal soil type. To indicate the strength of top soils a torsion shear meter has been built for comparisons of shear strengths of different soils, or of the same soil under different conditions.

11. Crop Behaviour During Mowing

In investigations into the process of mowing, the behaviour was studied of a dry flax crop being mown by a conventional and a double-knife mower. High-speed stereoscopic motion picture techniques were used to obtain accurate observations.

A detailed study has been made of crop behaviour, including slip on mower edges, departures from ideal cutting, and disturbance propagated in the crop ahead of the mower. The inertia of the crop was important in determining its behaviour, and an explanation has been obtained of the general absence of slip of straws along the advancing knife edge.

12. Flat Plate Solar Absorbers

A theoretical examination has been made of the effect of inclination and orientation on the amount of incident solar radiation on a flat surface at different latitudes. The angle of inclination to obtain equal incident energies at summer and winter solstices has been determined, and an expression derived which enables the inclination for maximum insolation over any period to be evaluated. As a close approximation, between latitudes 15 and 45°, the daily insolation at the summer solstice is equal to that at the winter solstice when the inclination is 1.5 times the latitude. Maximum insolation over a full year occurs when the absorber is inclined at 0.9 × latitude.

Neither inclination nor orientation is as critical as had been thought, and quite large departures from the optimum configuration can be tolerated without very significant reductions in incident energy. For example, in a latitude of 30° a 45° deviation in orientation from due north will produce a reduction in mean annual insolation of only 5%, as will a change in inclination from 0.9 to 1.5 × latitude.

13. Attenuation of Gas Pulsations in Compressors

Reciprocating compressors are in general noisy machines. This noise is primarily due to pressure pulsations in the compressor exhaust, the pressure waves being approximately sinusoidal in form. Reduction in the amplitude of these pulsations (and hence the noise produced by the machine) should be possible using wave interference. A silencer based on this principle would not adversely affect the efficiency of the compressor and would be preferable to the conventional muffler, which must inevitably increase back pressure.

Theoretical investigations of the attenuation obtainable by this method show that the amplitude of pressure pulsations at normal speed can be decreased by a factor of 7–10 when working with low back pressure. The energy of oscillations is therefore reduced 50–100 times, and a decrease in sound level by up to 17–20 db can be expected. This corresponds approximately to the transition from a factory noise level to that of a private residence.

Development of a practical wave-interference silencer is being investigated to apply it not only to compressors but also to other reciprocating machines with exhaust pressure pulses of roughly sinusoidal form. A preliminary design has been tested by using a twin-cylinder refrigeration compressor operating with air. Exhaust pulsations are being examined with pressure transducers, amplifiers, and a cathode ray oscilloscope. Test results showed good agreement with the predicted values.

The frequency of exhaust pressure pulses is a function of the speed of the machine, as well as of the number of single- or double-acting cylinders and the crank phase angle. It would appear, therefore, that an interference silencer would operate satisfactorily only with a constant-speed machine. Calculations and confirmatory tests have shown, however, that variations of as much as 10–15% in the compressor speed cause little reduction in the degree of attenuation obtainable in this way.

A patent application has been filed with respect to the new silencer.

14. Silage Loader

Silage is becoming an increasingly popular fodder among dairy farmers. It suffers, however, from the disadvantage of being difficult to remove from the pit or stack in which it has been made. To eliminate this laborious work a mechanical loader was developed by the Section in 1958 and extensively tested in the field during 1958–59.

The loader takes the form of a small swivelling jib crane, mounted on a turntable and suitably counterweighted. The crane rope is actuated through a pulley system by a hydraulic ram, and carries a tined grab on its free end. The ram is operated from the hydraulic system of a tractor through flexible hoses with quick-release couplings, a remotely controlled valve being used to determine its direction of motion.

The loader is intended for one-man operation, the tractor being used alternately to load the material and to haul it away. With a little experience, silage can be loaded at the rate of 6 tons per hr. This is about six times the rate at which a man can work for short periods.

15. Sliver Converter

The Division of Textile Industry at Geelong has been examining the drawbacks of the carding system as a means of producing wool slivers (*see* Chapter 27, Section 5). Modified pilot-scale commercial equipment has been used to straighten wool fibres, and the Engineering Section was asked to develop and build a production prototype machine with an output of 200 lb of wool per hour. This machine has now been built and is under test.

16. Application of Dissolved Gypsum to Pastures

Much of the soil in the Riverina area is unsuitable for irrigation, as water will not readily penetrate the impermeable surface layers. Furthermore, seeds do not germinate readily after irrigation, the hard surface crust preventing them from breaking through. This restricts the use of land for irrigated pasture.

Investigations carried out at the Regional Pastoral Laboratory at Deniliquin have shown that applying gypsum to the soil effects improvement. This can be done either dry, or in solution in the irrigation water.

Gypsum itself is relatively insoluble, and the Riverina deposits of this material contain a large proportion of sand. Collaboration between the Deniliquin Laboratory and the Chemical Engineering Section on this joint problem of gypsum dissolution and sand separation produced an approach which appeared likely to be successful (*see* Chapter 3, Section 13 and Chapter 33, Section 4(4)). The method proposed was to feed crushed gypsum into the suction side of an irrigation pump, and pass the discharge through centrifugal separators to remove sand and undissolved material. Agitation of the gypsum in its passage through the equipment would cause a high proportion to pass into solution.

The Engineering Section in collaboration with the Chemical Engineering Section has developed a prototype trailer-mounted machine, capable of supplying water containing dissolved gypsum at rates up to 2 cusecs. The completed machine has performed very satisfactorily in service.

17. Scale-Free Refrigeration Jointing Techniques

Among problems associated with production of hermetically sealed refrigeration systems is that of producing a system completely free from scale and other foreign matter. Scale produced during the jointing process will eventually be removed by the refrigerant and lodged in such places as compressor cylinders and crank-shaft bearings, causing accelerated wear of moving components, and also in capillary tubes causing complete or partial blockage.

Investigation has been undertaken to perfect a scale-free jointing technique. This work has been limited so far to the joining of copper to copper and copper to brass (as in the fabrication of tubing systems, direct expansion coils, and copper vessels), but it is intended to extend the work to welding of ferrous materials.

Each type of component or subassembly has its own problems, although the basic technique is the same in all cases. Surfaces to be joined must first be thoroughly cleaned. Oxidation of these surfaces during brazing must then be prevented by blanketing them with an inert atmosphere. For this purpose oxygen-free nitrogen has given very satisfactory results. Using this technique, under suitably controlled gas-flow conditions, joints can be brazed while the internal surfaces remain bright and free from scale.

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Agricultural Research Liaison Section

1. General

The Agricultural Research Liaison Section interprets results of research carried out by the Divisions and Sections of C.S.I.R.O. working for the agricultural and pastoral industries, and presents these results in a way which aids their adoption in practice. It does this by means of semi-technical publications, conferences, tours, and other activities designed to improve the flow of research information to State extension officers and others.

The work of the Agricultural Research Liaison Section is complementary to that undertaken by the Industrial Research Liaison Section, which promotes the use by Australian manufacturing industries of the results of C.S.I.R.O. research (*see* Chapter 48).

During the year the Agricultural Research Liaison Section established a Sydney office, in the New South Wales Department of Agriculture. This will be a liaison centre for the exchange of research information between C.S.I.R.O. and the State Department of Agriculture, and also for representatives of commerce and primary producers' organizations.

The Section participated with the University of Melbourne in a study led by Professor E. Wilkening, Fulbright Scholar from the University of Wisconsin, of forces influencing adoption of technological changes in rural communities.

2. Liaison Activities

Four issues of *Rural Research in C.S.I.R.O.* have been published during the year, providing extension workers, agricultural administrations, and leaders of the primary industries with an up-to-date account of progress of C.S.I.R.O. research in the soil, plant, and animal sciences. A leaflet was prepared entitled "Understanding the Cattle Tick", giving an account of the life history of the cattle tick, and implications of recent research on control of the pest. It was published in cooperation with the Queensland Department of Agriculture and Stock, and distributed by the Department to all dairy farmers and beef cattle owners in the tick areas of that State.

Display material and miscellaneous publications have also been produced for field days. Six numbers of the general series of *Liaison Notes* have been issued during the year. These notes are for limited circulation to extension workers, to give advance notice of, and supplement material published in, *Rural Research in C.S.I.R.O.* Horticultural and vegetable research newsletters have also been established in cooperation with State Departments of Agriculture.

Industrial organizations and such commercial groups as stock agents, agricultural and veterinary chemical manufacturers, and farm machinery firms all participate in disseminating new information, and their attitude towards new techniques of production influences their adoption in practice. Three liaison tours were arranged for representatives of primary producer organizations and commercial firms, embracing visits to C.S.I.R.O. research centres in Brisbane, Sydney, and Canberra.

The Southern Tablelands cooperative study between the N.S.W. Department of Agriculture and C.S.I.R.O. continued. This aims to assess existing and potential agricultural resources in the Southern Tablelands, and to explore how research and extension workers can best cooperate to mutual advantage. Special attention has been given to soil problems in the region. By applying the principle of soil layering developed by the Division of Soils, the principles used in interpreting the soil situation have been presented in a simplified form.

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Dairy Research Section

1. General

The Dairy Research Section aims to improve the quality, variety, and efficiency of manufacture of dairy products.

Other Divisions and Sections engaged in research on human foods are: the Division of Food Preservation and Transport (*see* Chapter 20); the Wheat Research Unit (*see* Chapter 19); the Division of Plant Industry, studying production problems of wheat and fruit (*see* Chapter 3); the Irrigation Research Stations, studying dried vine fruits (*see* Chapter 5); the Division of Fisheries and Oceanography, studying fish (*see* Chapter 14); the Engineering Section, studying storage of wheat and the temperature of baking ovens (*see* Chapter 16); the Division of Entomology, studying insect pests of stored grain (*see* Chapter 11, Section 13).

The activities of the Dairy Research Section have been strengthened during the current year by grants from the Australian Dairy Produce Board. The Section has been asked to play a major role in the manufacturing research program which is being supported by the industry, and to provide assistance and service to other groups. Two conferences on dairy manufacturing research have allowed much progress to be made in linking and coordinating all Australian activities in this field.

The work of the Section is being expanded. Deficiencies in scientific equipment for flavour chemistry and milk protein investigations are being made good by the acquisition of such major items as an infra-red absorptiometer, a recording spectrophotometer, and an ultracentrifuge. Additional staff are being appointed.

Many of the investigations of the Section have in the past called for close cooperation with State Departments of Agriculture and with the universities. The Section has continued to work closely with the Australian Dairy Produce Board, the Cheese Manufacturers' Federation, the Casein Manufacturers' Association, and the Queensland Butter Marketing Board. It has continued to support technical extension and educational activities of the Australian Society of Dairy Technology, and has received constant and unstinted assistance from the Dairy Export Division of the Department of Primary Industry.

2. Cheese

A major achievement has been the successful commercial introduction of the curd milling, salting, and hooping unit developed by the Section. Manufacture of the unit and its commercial use have called for continued work in close cooperation with dairy engineering and cheese manufacturing firms. At the same time substantial progress has been made with the design of the full-scale curd-fusing unit, now adapted for use with the orthodox Cheddar cheese-making process.

The first commercial manufacture of "Cheedam", a variety of cheese developed by the Section, has also called for cooperative work with the industry.

Laboratory investigations have been concerned with the syneresis of rennet coagulum, with inhibitory effects on lactic acid production in milk, with factors affecting the growth of blue mould, with the relative usefulness of measurements of pH, conductivity, and titratable acidity in controlling the cheese-making process, and with factors responsible for freeing water, which sometimes takes place in maturing cheese.

Pilot plant tests have been made on low-temperature drying of cheese, a process of potential commercial utility in the use of off-cuts from pre-packaged cheese and in providing cheese in a convenient form for use in baked goods.

Export of cheese to Great Britain in rindless form has passed out of the first experimental stage and is undergoing steady commercial expansion. Improvements in technique are still being made, however, and the Section continues to play an active role in this development.

3. Butter

Further experiments with surface deterioration in cold-stored butter have confirmed earlier indications that desiccation of butter at the surface inhibits fat oxidation. Incubation of samples of parchment in butterfat confirmed that pro-oxidant substances were present in the parchment, and this oxidative effect correlated well with the copper contents of the parchments. An attempt to develop a rapid method to determine the oxidative effect of parchments has not yet met with success.

To develop improved techniques for determination of copper in butter, support has been given to the work on atomic absorption spectra being carried out by the Division of Chemical Physics. A study has also been made of the efficiency of acid extraction procedures under various conditions.

The precise relationship of malonic dialdehyde to the thiobarbituric acid test, widely used as an index of oxidation, has been investigated.

A comprehensive review of recent work on the chemistry of butter and butterfat was prepared for the *Journal of Dairy Research*.

4. Casein

A survey of quality and manufacturing problems in the casein industry showed that while recently introduced methods of continuous precipitation saved much labour, subsequent washing procedures allowed insufficient time for removal of impurities, mainly lactose and ash, from the casein to the detriment of its commercial quality. Improved equipment, making use of inclined screens for separating casein from whey in wash water, has now been tested and is entering commercial production. A fluorescent staining technique was developed to permit the path of casein particles through the prototype equipment to be followed. More recently attention has been concentrated on the effect on quality and yields of conditions of agitation and rapidity of interaction at the point of addition of acid to the skim milk.

5. New and Modified Products

Preliminary tests have been made on the use of butterfat in prepared cake mixes. This work forms part of a long-term project on the use of butterfat in prepared foods.

Techniques have been studied for the production of cheese cake, a dessert highly esteemed and widely used in the U.S.A., but little known in Australia, and of the cheese best suited to its production. The product has been brought to the attention of the promotional section of the Australian Dairy Produce Board.

Cottage cheeses of various types have been produced and the attention of the dairy industry has been directed to their commercial potential.

6. Recombined Dairy Products

The Australian dairy industry is becoming increasingly aware of the potential for plants in Asiatic countries producing recombined dairy products. Particular attention was given to methods for recombining sweetened condensed milk. In the method finally developed certain technical precautions permit all ingredients to be mixed together, homogenized, and vacuum treated to give a very satisfactory product.

7. Flavour Chemistry

Investigations continued into compounds responsible for various types of flavour arising from oxidative deterioration in lipid constituents in dairy products. In addition to the techniques of gas and liquid chromatographic separation and identification of carbonyl compounds as their 2,4-dinitrophenylhydrazones, increasing use has been made of ultraviolet and infrared absorptiometry and of mass spectrometry. In particular the high-resolution mass spectrometer recently completed at the Division of Chemical Physics (*see* Chapter 29, Section 4(i)(1)) has provided valuable information. The assistance given in this work by officers of the Division of Chemical Physics is gratefully acknowledged.

A comprehensive picture of the range, types, and relative concentrations of the compounds causing such flavours as "cardboard", "oily", "tallowy", "painty", and "fishy" is now emerging. Much of the work has already been prepared for publication and the investigation is nearing completion.

Gas chromatographic techniques are being applied in studies on weed taints. Assistance was given to the Division of Entomology by the characterization of the aldehydes responsible for the odours of five species of insects.

8. Microstructure

Improved techniques for observation of the microscopic structure of dairy products have been applied to two main problems: the effect of various reagents on the state of dispersion of casein, which has given information on the chemical bonding within the casein micelle or coagulum; and the form of aggregation, particularly of the fat and casein, in the insoluble particles which are present in all milk powders and give rise to undesirable scum or sediment.

9. Miscellaneous Investigations

Comparisons have been made of the initial and keeping qualities of a variety of baked goods made with butter and with various margarines.

Assistance has been given to the industry on a number of occasions in such matters as the control of bacteriophage in cheese factories, the manufacture of Camembert cheese, and analytical control methods.

The possibility of using protective forms of glass in milk bottles to minimize the harmful effects of sunlight on milk is being re-examined. A batch of amber-glass bottles has been made by local glass manufacturers and their usefulness is being assessed.

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Wheat Research Unit

1. General

The Wheat Research Unit is a laboratory recently established by C.S.I.R.O. with funds provided by the Wheat Industry Research Council to investigate factors affecting the quality of Australian wheat. The Unit has been attached to the Bread Research Institute of Australia. The two establishments are concerned with similar problems, and the work of the Unit is well integrated with that of the Institute.

The Division of Plant Industry studies aspects of the genetics of wheat (*see* Chapter 3, Section 3) and also the physiology of wheat grains and seedlings (*see* Chapter 3, Section 7); the Division of Entomology undertakes research on the control of insect pests in stored grain (*see* Chapter 11, Section 13); and the Engineering Section also studies problems associated with the storage of wheat (*see* Chapter 16, Section 9).

The Wheat Research Unit in December 1959 moved into its new laboratories in the building recently erected for the Bread Research Institute at North Ryde, N.S.W. Most of the staff joined the Unit during the first quarter of 1960.

2. Research Projects

Research has begun on the role of protein in determining wheat quality. The first, and basic, problem is that of bringing all the protein of a flour into solution as a preliminary to its examination by biochemical and physical methods. Concurrently the non-protein nitrogenous fractions of flour present both before and after doughing are being examined in relation to protein changes during dough maturation. There is little doubt that many enzymes in flour will be in an adsorbed state in a dough. Work has therefore begun on the effect of adsorption of enzyme action. This work should lead to a better understanding of the role of enzymes in dough maturation.

Work has begun in collaboration with the Waite Agricultural Research Institute on the separation of extractable wheat proteins with a view to subjecting these to physical examination.

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Division of Food Preservation and Transport

1. General

The Division of Food Preservation and Transport is the main centre in C.S.I.R.O. undertaking research on food, particularly preservation of food during storage and transport before marketing. Even more perishable foods are now being conveyed great distances between producer and consumer, and as a food exporting country Australia has a vital interest in food preservation problems.

Other Divisions and Sections engaged in direct research on human foods include: the Dairy Research Section investigating dairy products (*see* Chapter 18); the Wheat Research Unit studying the quality of Australian wheats (*see* Chapter 19); the Division of Plant Industry studying production problems of wheat and fruit (*see* Chapter 3); the Irrigation Research Stations studying the production of fruits and vegetables under irrigation and the processing of dried vine fruits (*see* Chapter 5); the Division of Fisheries and Oceanography studying fish (*see* Chapter 14); the Engineering Section studying the storage of wheat and the temperature of baking ovens (*see* Chapter 16); and the Division of Entomology investigating insect pests of stored grain (*see* Chapter 11, Section 13).

The Division of Food Preservation and Transport has its main laboratories at Homebush, N.S.W., and Branch Laboratories at Brisbane (meat); West Gosford, N.S.W. (citrus fruits); Hobart (fish, apples, and berry fruits); and at the Botany and Biochemistry Departments, University of Sydney (plant physiology and physical chemistry).

Construction of the Division's new laboratories at North Ryde has made substantial progress, and it is expected that they will be occupied by June 1961.

In December 1959 Dr. R. N. Robertson, Assistant Chief, transferred from the Division to take up his appointment as a Member of the Executive. Dr. D. D. Davies of the University of London has been appointed to succeed Dr. Robertson as Joint-leader of the Plant Physiology Unit.

Research in cooperation with universities and with Government Departments and instrumentalities has been continued. In November 1959 the Division arranged a conference on the Control of Food Quality. This was held at the University of Sydney and attended by over 100 scientists from industry, and research and teaching institutions.

In May 1960 the Chief of the Division, Dr. J. R. Vickery, attended the Pacific Rim Food Conference in Hawaii and the 20th Annual Meeting of the Institute of Food Technologists in San Francisco. While in San Francisco Dr. Vickery received the Institute's 1960 International Award.

2. Physics

(1) *Canning Processes*.—A paper has been published on errors caused by conduction when thermocouples are used to measure temperature in heat penetration experiments. A second paper dealing with the cooling phase of the canning process has been accepted for publication. A manuscript written by the late E. W. Hicks is being prepared for publication; it deals with accuracy and safety factors in process evaluation.

Fresh calculations have been made on the effects of taking tangents to heating curves, since the only publications on this matter are known to be considerably in error.

(2) *Freezing Points of Fruits*.—It has been suggested that the apparent freezing point of living plant tissue is lower than that of dead tissue because of the effect of rate of ice formation on measurements. Storage experiments with pears have shown that freezing will occur eventually in whole fruits at a temperature slightly below the freezing point of dead tissue. Slight injury of fruits was found to favour freezing. Tests on fruit stored for several months showed that the apparent freezing point of living tissue was still significantly lower than that of tissue damaged by freezing, or extracted juice.

(3) *Evaporation from Fruit in Cool Storage*.—Evaporation properties of single apples and pears have been studied in detail.

Measurements on diffusion of carbon dioxide within a bushel case of fruit have been in good agreement with predictions from an electrical analogue. A similar method is being used to study diffusion of water vapour within a case of fruit. Weight losses of fruit packed in cases of special design are being used to check a theory on the evaporation and diffusion of water vapour.

It has been found that the permeability of the corrugated fibreboard used in making bushel cartons increases rapidly at high humidity and that this modifies the beneficial effect of maintaining a high humidity in the store for the purpose of reducing wilting.

(4) *Measurement of Relative Humidity*.—Work continued on development of probes suitable for determining the relative humidity of storage spaces. The technique of producing anodized aluminium probes has been standardized. Overseas these probes have proved sensitive to vapours other than water, and

unsatisfactory at high humidities and low temperatures. Other sensitive materials have been tried and progress has been made in developing probes with satisfactory response, stability, and freedom from hysteresis.

(5) *Freeze Drying.*—The freeze dryer for drying microorganisms has been further developed to obtain a prescribed uniform water content in microorganisms in the final stages of drying.

(6) *Theory of Heat and Mass Transfer.*—During 1957–59 an officer of the Section worked at the Imperial College of Science and Technology on the theory of heat and mass transfer through laminar boundary layers. This work is being continued at Homebush.

The equations which govern the distribution of velocity and a conserved fluid property for laminar boundary layers in forced convection are well known. For any specific problem these equations must be solved simultaneously.

For certain systems, however, the equations reduce to ordinary differential equations which can be solved exactly. By plotting certain functions obtained from these solutions, approximate methods have been evolved which may be applied to any laminar boundary layer. These methods (which involve the use of tables and charts) include the effects of (*a*) main-stream acceleration; (*b*) mass flow through the wall boundary, both inward and outward mass flow being included, and (*c*) the fluid property group which is the Prandtl number for calculating heat transfer or the Schmidt number for mass transfer.

The velocity equation has been covered for a wide range of main-stream acceleration, but two regions in the accelerated zone and the highly accelerated zone still need consideration.

The conservation equation still requires more attention. Behaviour of the solutions at very high and very low values of Prandtl (or Schmidt) numbers are known, and formulae have been developed giving solutions within a few per cent. at intermediate values. More exact solutions are being sought.

Examination of the case when no mass flows through the wall boundary is well advanced, functions being known accurately for all values of the Prandtl number except a narrow region between 0.01 and 0.5.

3. Food Chemistry

(i) *Anaerobic Decomposition of Ascorbic Acid*

This reaction is responsible for the loss of ascorbic acid (vitamin C) from stored canned foods. Work over a wider range of pH has shown that decomposition is promoted by increasing acidity below pH 2. The effect of various factors on the yield of furfural has been studied.

(ii) *Chemical Factors in Superficial Scald*

The relation of superficial scald, a functional disorder of stored apples, to ventilation suggests that it is caused by volatile substances produced by the fruit itself. As the volatile substances which have been identified do not appear to be concerned, the study is continuing of unidentified substances, including those with ultraviolet absorption. In experiments with chemical inhibitors no other substance has been found as effective as diphenylamine, although benzylaniline is nearly as effective. The effect of diphenylamine on the production of volatile substances is being studied.

(iii) *Volatile Substances of Foods*

The facilities for work on volatile substances are being extended to include flavouring constituents of foods. Various types of gas chromatography apparatus are in course of construction, and identification of the components by infrared or mass spectroscopy are being studied. Gas chromatography has been used to identify a number of constituents of apples.

(iv) *Properties of Ethylene Dibromide*

As a result of unaccounted losses in the fumigation of oranges with ethylene dibromide (to destroy larvae and eggs of fruit fly), absorption and possible destruction of this substance are being investigated. Materials used in fumigation are being tested systematically in an all-glass model system.

(v) *Lipids in Food Preservation*

Work on lipids is concerned with their part in the structure of plant and animal tissues, as this influences storage behaviour. The natural coating of apples controls gas exchange and is also a factor in the incidence of superficial scald. In a study of the oil fraction of this coating the fatty acids have been identified and work commenced on the unsaponifiable matter. Studies of changes in the lipids of avocado fruits during development and storage have recently been published. Work commenced on the lipid associated with actomyosin, the contractile protein of muscle.

(vi) *Chemistry of Non-enzymic Browning*

Dried and concentrated foods suffer serious deterioration in storage through non-enzymic browning and accompanying changes in flavour and solubility. Progress has been made in elucidation of the chemical reactions involved.

(1) *Characterization of Intermediates*.—A further step has been clarified in the sequence of reactions occurring in an aldose-amine system. It has been shown that a 3-deoxyhexosone is the main carbonyl compound formed in the breakdown of a diketose amino acid. The two possible 3-deoxy-D-hexosones have been synthesized in a pure state and their reactions with acids and alkali studied. There is thus established a mechanism for the conversion of aldoses to dicarbonyl compounds which could promote the Strecker degradation of amino acids as well as participate in browning reactions.

(2) *Reactions of Bisulphites*.—Sulphur dioxide and bisulphites are used to inhibit browning in foods. Reactions of bisulphites and sugars, under mild conditions, have been shown to extend beyond the formation of addition compounds previously reported. Conversion of bisulphite to sulphate and sulphur was promoted by reducing sugars, with concurrent oxidation of the sugars. Aldoses

were oxidized to aldonic acids and ketoses to keto acids. Inhibition of browning by bisulphites may be due to oxidation of the carbonyl compounds formed in the aldose-amine sequence of reactions.

(3) *Factors Affecting Browning.*—Factors affecting different stages of the aldose-amine reaction sequence are being studied in relation to conditions affecting development of brown colour. This will help in relating results obtained in model systems to effects observed in dried foods. It has been found that acid-base catalysts which promote formation of ketose amino acid have a proportionate effect on browning, but the addition of inactive solutes depresses browning without altering the rate of formation of ketose-amino acid.

(vii) *Protein Chemistry*

Studies are complete on denaturation of ovalbumin by heat and the effects of temperature on molecular properties of the β-lactoglobulins. Ovalbumin, heated in solution at pH 3, undergoes a partial expansion or unfolding followed by a series of aggregation stages. The first reaction (change in conformation) is much less extensive than that brought about by urea. Aggregation stages are influenced markedly by amount of salt present, and, together with conformation change, are irreversible. An ovalbumin fraction which does not take part in these reactions has been isolated and is being studied.

Measurement of average molecular weights in the ultracentrifuge at different temperatures and protein concentrations has shown that β_A-lactoglobulin associates to form a tetramer at 4°C, whereas β_B-lactoglobulin does not change. Association of β_A-lactoglobulin at pH 4.7 was found to be quite reversible and dependent only on temperature and concentration. The association constant for the reaction at 4°C has been calculated.

Reaction between fish myosin and a reagent which combines with sulphydryl groups (*p*-chloromercuribenzoate) was studied as a possible method of reversibly inactivating the myosin ATP-ase. The reaction proved irreversible and the reagent was found to cause aggregation of myosin and partial dissociation of actomyosin. Myosin and actomyosin were also prepared from beef, by using modifications of methods developed for fish muscle, and have been examined in the ultracentrifuge. By using a variety of extracting media assessments have been made of the amounts of myosin and actomyosin extractable from fish and beef muscle stored at 4°C, and fish which had been frozen and thawed.

Investigation of the water-holding capacity of muscle breis and muscle protein gels, in relation to the problem of "drip" in frozen and thawed beef, has been commenced. Effects of pH, salt concentration, and specific ions on gelling and flocculation of actin-myosin suspensions are being studied, and will be compared with parallel measurements of size and shape change in solution. Definition of water-holding capacity in terms of the rheological properties of gels and suspensions is also being studied to develop a better method of measurement.

4. Microbiology

(1) *Water Relations of Microorganisms.*—Earlier studies of relationship between bacterial cell composition and water activity of growth medium were made with *Staphylococcus aureus* as test organisms. These experiments have now been extended to some additional organisms. The chemical composition of 32 different bacteria has been studied after growth in the same medium. In separate experiments the minimum water activity permitting growth was determined for each organism. For all organisms there was a highly significant negative correlation between potassium content of the cells and minimum water activity at which growth occurred. Some other associations between chemical composition and water requirements were observed, but they were not the same for different groups of bacteria.

Experiments with *Staphylococcus aureus* and *Pseudomonas fluorescens* have determined the extent to which salt tolerance is modified by changes in environmental temperature and pH. Maximum salt concentrations permitting growth were greatest at the optimum temperature and under slightly acid conditions. Salt tolerance was reduced appreciably at temperatures approaching the minimum for growth. Comparable experiments with *Clostridium botulinum* are still in progress. Studies commenced of the effect of water activity on bacterial heat resistance with *Staphylococcus aureus* as the test organism.

(2) *Bacterial Spores.*—Studies commenced on the chemical composition of bacterial spores, and an exploratory series of comparative analyses of spore coats and contents of four species of *Bacillus* has been almost completed. So far no major differences have been observed although the spores selected differed widely in their resistances to heat. Experiments have been discontinued on the permeability of spores to heavy water. Although results suggest that all the water in spores mixes freely with external water, they do not conflict with the possibility that part of the spore contents is substantially dry. Study of the fine structure of spores has been commenced, with the use of the electron microscope and very thin sections of intact spores and spore coats. A review of the effects of environment on the formation, properties, and germination of bacterial spores has been prepared for publication.

(3) *Drying of Microorganisms.*—The equipment used for drying microorganisms under controlled conditions has been modified, and it is now possible to control the extent to which the initial drying proceeds. An experimental study of this variable is in progress. Experiments continued on the production of neutral and acid carbonyl compounds during storage of dried cells, and some neutral substances produced have been provisionally identified. Continued storage has been found to lead to breakdown of many carbonyl compounds generated during the earlier part of the storage period.

(4) *Irradiation of Microorganisms.*—Experiments commenced on the irradiation of bacterial spores at several controlled moisture levels, in the presence and absence of air at several temperatures. The effects of these variables are not independent.

5. Muscle Biochemistry

(1) *Thaw Rigor.*—An attempt is being made to define the biochemical factors influencing shortening, during thawing, of muscle frozen prior to rigor, and also to explain the acceleration of post-mortem changes during onset of thaw rigor. Shortening of frozen muscle on thawing has been shown not to be restricted to muscle frozen before onset of rigor mortis.

(2) *Muscle Extensibility and "Rigor Contraction".*—A study is being made of biochemical changes in post-mortem muscle, and their relation to changes in muscle extensibility and the contraction associated with onset of rigor mortis.

(3) *Comparative Studies.*—In connexion with the above investigations, mechanical and biochemical changes in psoas and longissimus dorsi muscles of rabbits, sheep, and cattle are being examined and compared.

(4) *Inosine Monophosphate Degradation.*—This project, initiated at the Division's Meat Research Laboratory, Brisbane, is being continued, to define the major pathway by which inosine monophosphate is degraded to hypoxanthine.

6. Meat

(1) *Meat Quality.*—Since the reactions of meat to freezing and thawing may be best explained in terms of the physical and chemical properties of muscle tissue, work in this field has been concerned mainly with the properties of fresh meat and its flavour and texture when cooked. The influence of intravascular injection of specific chemicals into the slaughtered animal has been studied on carcasses for chilling and for freezing. Chemicals which modify the response to freezing also modify the texture of cooked fresh meat. The technique has been used to inject chemicals for reducing drip from thawed-out frozen meat, and enzymes to increase the tenderness of meat. Promising results have been achieved, and studies are being made of the effects of time of injection and storage conditions.

In cooperation with the National Cattle Breeding Station at Rockhampton, a program has been commenced on the influence of breed and of individual sires on eating quality. Differences observed will be correlated with physiological characteristics to see whether selection can be made on the basis of meat quality, and if so, whether this will be compatible with selection for such characteristics as heat tolerance and weight gain.

(2) *Meat Transport.*—The shanks on much Australian chilled beef arriving in the United Kingdom in the 1960 season have been greatly desiccated, causing a dark discoloration of areas with light fat cover and a corrugated appearance. A number of shipments are being examined to determine the causes, and possible remedies, of this defect.

(3) *Bacteriology.*—Studies are in progress on the hygiene of slaughter floors and chilling rooms. Since much of the bacterial load on a dressed carcass originates on the hide of the steer, attempts have been made to sterilize the hide

on the live animal. However, fully effective techniques appear impracticable on economic grounds. Pasteurization of the carcass at the final stage of the dressing operations is also being investigated. The effects of time and temperature of pasteurization on the bacterial load and bloom of the carcass are being examined.

Laboratory studies have shown that aerosol sterilizing agents such as lactic acid can considerably increase the death rate of air-borne organisms. When the optimum conditions of humidity and concentration at a given temperature have been worked out it should then be possible in pilot-scale tests to establish whether aerosols can significantly reduce the bacterial population in the air or on the structures of a commercial chiller.

(4) *Freezer Burn.*—It is now possible to describe in detail the effects, at normal freezer store temperature, of the condition of the liver, rate of freezing, degree of evaporation during freezing, and rate of evaporation during storage on the incidence of freezer burn on frozen livers. Histological studies have clarified the physico-chemical processes underlying the production of the defect. It may now be possible to control this by dipping the livers in concentrated solutions of hexoses and other chemicals before freezing. Studies are being extended to other offals and meat cuts, and to embrace several storage temperatures.

(5) *Nitrite Discoloration of Carcass Meat.*—Investigations continued on the brown discoloration of exposed muscle surfaces and bleaching of adjacent fatty tissues of beef and mutton carcasses during chilled storage. Work has been done on the growth characteristics of, and nitrite production by, the microorganisms (*Nitrosomonas* spp.) involved.

7. Fish

Spoilage of Fish Products.—The condition of fish despatched by refrigerated road transport from the Great Australian Bight to Sydney was examined. Several cases of spoilage in fish and prawns were investigated.

8. Eggs

(1) *Disorders in Eggs.*—Investigations continued on the natural occurrence of malvalic and sterculic acids, known to give rise to "pink-white" disorders in eggs when ingested by hens. Oil from cottonseed (*Gossypium hirsutum*) has been found to contain a total of 1% malvalic and sterculic acids, occurring in the ratio of about 10 : 1. The seed oil fatty acids from *Sterculia foetida* contain 60% sterculic acid and 10% malvalic acid, although published reports had indicated 70% sterculic acid only.

(2) *Egg Quality.*—A survey is being made of the internal quality of eggs at various stages during marketing in Australia. At some periods of the year the quality of eggs being retailed is below the standards considered acceptable. Examinations are continuing on the influence of production and marketing factors on egg quality in retail shops.

9. Fresh Fruit and Vegetable Storage

(i) *Plant Physiology and Biochemistry*

Mitochondria, the centres of cellular respiratory activity, were studied further, attention being given to the correlation between structure and function. The role of the cofactors diphosphopyridine nucleotide, coenzyme A, and lipoic acid in mitochondrial respiratory pathways was investigated. This has yielded better understanding of the electron transport chain.

Work on the ionic relations of the large-celled alga *Chara australis* continued with special regard to the fluxes of sodium into and out of the vacuole. Measurements of the electric properties of the membranes in these cells were extended. It was established that resistance and potential difference are functions of membrane permeability to potassium and sodium ions.

Influence of environmental conditions on growth of peas, and especially on carbohydrate metabolism, was again studied with peas grown in the phytotron at the California Institute of Technology. Peas grown at 14°C (day temperature) had a higher sugar content and lower starch content than those grown at 17°C.

Investigations continued on the enzymes involved in sucrose synthesis in plants. Nucleoside monophosphokinase, which forms uridine diphosphate, was isolated from pea seeds and its properties studied.

Glucose 1-phosphate is usually considered to be the precursor of starch in plants. Evidence having been obtained that in animal tissues glycogen may be formed from uridine diphosphoglucose (UDPG), experiments were undertaken with plant extracts to ascertain if starch could be formed from this compound. Evidence was obtained of polysaccharide formation from UDPG by plant tissue extracts. An enzyme was found to be present which catalysed a reaction between UDPG and glucose 6-phosphate to give the monophosphoric ester of the disaccharide trehalose.

Further work was carried out on conversion of adenosine nucleotides to the guanosine series. It is believed the latter compounds will prove important in carbohydrate metabilosm. The enzymes responsible for the first two steps considered likely in this conversion are adenylic deaminase (adenosine monophosphate to inosine monophosphate), and inosine monophosphate dehydrogenase (inosine monophosphate to xanthosine monophosphate). These two enzymes were successfully prepared from pea seeds extracts and their properties studied.

The perchloric acid extraction technique commonly employed for estimating phosphoric compounds in tissues has been shown to cause substantial losses of some of these compounds, and a method to overcome this difficulty has been devised.

Various extractants were compared for removing soluble nitrogenus compounds from plant tissues. Tests with pea seeds and hulls showed that a buffered sodium chloride solution was the most effective. A monograph on nitrogen metabolism in plants was prepared for publication.

Although oxalic acid is widely distributed in plants, very little is known of its metabolism and biological significance. An investigation was undertaken to ascertain if oxalate is metabolized and, if so, to elucidate the mechanism involved. Slices from seedlings of a number of plant species were taken and it was found that all formed $^{14}CO_2$ from oxalic acid -1,2-^{14}C. A cell-free preparation from germinating pea cotyledons was obtained which converted oxalate -^{14}C to $^{14}CO_2$. The system requires adenosine triphosphate and coenzyme A.

(ii) *Fruit Storage and Related Problems*

Research continues in these fields in close cooperation with the New South Wales Department of Agriculture at Homebush and at the Citrus Wastage Research Laboratory, Gosford. Most of the work at Homebush has been directed to problems in the cool storage of apples and pears, the main fruits stored in Australia. Transport and marketing problems have also received much attention.

(1) *Apples.*—Investigations on storage in controlled atmospheres (C.A.) continued. The separate effects were studied of carbon dioxide and oxygen on Granny Smith apples, the main variety cool stored. The incidence of superficial scald, which is the main problem in the storage of this variety, is greatly reduced in a storage atmosphere containing low levels of oxygen. When scald was controlled by treating fruit with diphenylamine best results were obtained in an atmosphere containing 5% of carbon dioxide and 2–3% of oxygen, and fruit was in very good condition after 6–7 months' storage. With the Jonathan variety an atmosphere of 0% carbon dioxide and 2–3% of oxygen gave very good results.

Study of the use of thin polyethylene film bags or box liners as a storage aid was continued. Granny Smith apples keep well in polyethylene, provided scald, which is worse in these bags, is controlled with diphenylamine; but flesh breakdowns after storage has often been greatly increased in Delicious and Jonathan varieties. Reasons for this are being studied, and it is considered that high humidity may be a factor.

Variability of the atmosphere in polyethylene bags has been investigated, and the causes elucidated.

Control of superficial scald by spraying apples with diphenylamine before harvest has again been demonstrated, and the relation between spray concentration and time before harvest investigated. Application of diphenylamine by impregnation into tray and cell packs in fibreboard cartons is being studied.

Work on the relationship between tree nutrition and fruit quality in apples (undertaken in conjunction with the New South Wales Department of Agriculture) was temporarily suspended. Quality assessment of fresh apples by tasting panels was continued.

Bulk bins are rapidly being introduced into the fruit industry for the cool storage of apples, and a study is therefore being made of the effects of these bins. Even bins with no side or bottom ventilation cooled more rapidly than a single box of wrapped and packed fruit. Rate of cooling in a bulk bin of a given shape seems to depend more on bottom venting than on ventilation of the sides.

(2) *Pears.*—Controlled atmosphere storage studies continued. An atmosphere of 5% carbon dioxide with 2–3% of oxygen proved suitable for the varieties Williams, Bosc, Packham's Triumph, and Josephine, but not for the variety Winter Cole.

Williams, Bosc, Packham's Triumph, and Josephine pears stored well in sealed polyethylene box liners, provided precautions were taken to avoid excessive concentration of CO_2 and depletion of oxygen. The Winter Cole variety developed flesh collapse ("brown heart") when the CO_2 concentration exceeded about 5%. Brown heart was induced in Packham's by several weeks' cool storage in air before sealing in polyethylene liners. Control of blue mould wastage during storage and marketing has been obtained by using a sodium orthophenylphenate dip, but pH control was necessary to avoid skin injury.

(3) *Citrus Fruits.*—Effectiveness of the widely used sodium orthophenylphenate dip for controlling green mould may be improved by supplementing it with a wax emulsion containing phenate. The treatment, if successful, could replace diphenyl impregnated fruit wraps on fruit for more distant markets. Several new fungicides were tested against green mould but none were promising.

Development of mould during degreening of citrus fruits can be controlled by introducing ammonia into the colouring room, thus avoiding the necessity for putting the fruit through a phenate dip treatment before degreening.

Good control of wastage by stem end rot was obtained by including sodium salicylanilide in a wax emulsion dip. Development of black spot in Valencia oranges during marketing may be reduced by post-harvest treatments, such as waxing, which reduces water loss from the fruit.

(4) *Fruit Development.*—The electron microscope has been used in growth studies over a number of seasons on oranges, apples, and pears to examine the fine structure of the fruit cells.

(5) *Transport.*—Rail transport of tomatoes from north Queensland to Sydney was studied and improvements suggested. Work on tomato transport is continuing.

(6) *Fruit Fly* (*In cooperation with the N.S.W. Department of Agriculture*).—Since outbreaks of fruit fly have occurred in many citrus growing areas in Australia, development of a sterilization treatment acceptable to quarantine authorities in countries importing Australian fruit has become imperative.

At the Gosford laboratory studies continued on the post-harvest disinfestation of oranges by fumigation with ethylene dibromide (EDB). Investigations concluded on fumigation with 16 oz EDB per 1000 cu. ft. for 2 hr at 70°F, and work is now being concentrated on fumigation at temperatures below 70°F. So far, at a temperature of 50°F, there has been only one survivor out of 14,000 larvae fumigated at a dosage of 24 oz EDB/1000 cu. ft. for 2 hr and no survivors out of 14,000 at a dosage of 32 oz. Fruit injury under these conditions is being studied with early Navel oranges which are most susceptible to skin damage by EDB.

(7) *Removal of Spray Residues from Apples and Pears* (*In cooperation with the N.S.W. Department of Agriculture*).—Residues of pesticidal sprays on harvested fruit, which are often unsightly and may constitute a health hazard, are a potentially

serious problem, especially on overseas markets. In a survey in New South Wales in 1959, covering 53 samples and 8 common pesticide residues, residue levels, with one exception, were all within accepted tolerances.

An experimental washing machine has been built and a number of different residues have been satisfactorily removed by washing. Some of the newer, more effective pesticides present less of a residue problem than older materials, being either less obvious at harvest or more easily removed by simple means such as dry brushing.

10. Canning and Fruit Products

Such good progress has been made in the study of technological problems of fruit and vegetable canning that it has been possible to change the emphasis of the work towards more basic investigations on processed foods. Much of the testing of varieties of canning crops has been satisfactorily completed, and laboratory resources and personnel may be diverted to studies of processing changes in the primary quality factors of colour and texture. Work on the chemistry of anthocyanins is already well developed, and facilities have been provided for an intensive investigation of texture. Research already carried out on the maturation and processing of green peas will provide a valuable starting point for textural studies.

(1) *Vegetable Canning*.—The new motorized pea maturometer was commercially tested and found to agree in performance with the standard model. When fitted with the redesigned quick-loading sampler plate the instrument is more convenient to use than the hand operated maturometer.

Further work on water blanching of peas for canning confirmed the adequacy of the 30 sec process at 200°F. Elimination of gas was still more rapid when peas were blanched in steam at atmospheric pressure, but this treatment was found to cause physical damage to the product. Peas canned after blanching in water for 30 sec were judged by taste panels to be superior to unblanched peas and to peas blanched for longer periods.

Investigation of comparative performance of mobile and stationary pea harvesters continued. Peas processed after mobile harvesting showed more damage in the can than those from the stationary machine.

(2) *Fruit Canning*.—A major problem of taint in canned peaches and in canned, diced peaches and pears was investigated and found due to excessive chlorination of the water supply at the processing plant. The characteristic condition was reproduced experimentally by addition of free chlorine to taint-free packs.

Work commenced on measurement of fragility in pineapple slices. This condition causes broken slices on the cannery packing table. Modified radial and concentric maturometer cutting heads give texture values that correlate well with a direct break test, and indicate fruit-to-fruit variation. The investigation will be transferred to a pineapple cannery.

Some of the apricots canned commercially during the 1958–59 and 1959–60 seasons gave abnormally soft and, in some cases, completely disintegrated canned products. Chemical examination of sample cans from canneries in New South Wales and Victoria showed that the quantity of protopectin, which is largely responsible for the firmness of fruit tissue, was less in soft fruit than in firm fruit taken from the same can. Although it is well known that protopectin disappears as fruit matures, there were no other indications that the abnormal fruit was more mature when canned than the firm fruit.

In view of suggestions that unusually hot weather during maturation of the fruit had affected the normal ripening process, a preliminary investigation was undertaken at Homebush to determine whether high temperature ripening (100 and 120°F) would cause breakdown in the can. None of these treatments resulted in abnormal softening of the fruit nor in changes in the protopectin content of the fruit.

Further investigations have been made on the problem of pink discoloration in canned pears, which arises from the apparently random occurrence of fruit containing high concentrations of leucoanthocyanins. A survey was undertaken to study the effect of 25 variables in field conditions and 18 variables of storage and maturity factors on the leucoanthocyanin content of pears. This covered 12 orchards in the Goulburn Valley, some of which were found to contain trees bearing fruit slightly more susceptible than others to this discoloration. However, while it is apparent that field factors may be important, the study of this aspect of the problem is complicated by the over-riding effect of seasonal variations, produced most probably by climate and rainfall differences. Nevertheless the investigations have demonstrated that storage conditions and maturity at picking are of very great significance in this problem.

In berry canning investigations at Hobart the effects of agitated or spin cooking on the quality of canned raspberries and strawberries were examined. Breakage may have increased slightly at lower speeds with increasing rate of rotation, but the main quality differences correspond to time of cooking.

In a comparison of canned berries processed to different centre temperatures, there was no improvement in quality by cooking to temperatures above 180°F.

The final quality in all experimental packs was affected far less by processing variables than by the condition of raw material at the point of processing.

Experimental packs of double-strength apple were prepared by dehydrocanning. A product of quality comparable to normal solid pack pie apple can probably be prepared by this process. Two main preparation problems, both of which occur during the drying stage, are discoloration of the product and variation in rate of water loss. The dehydro-canned product requires no soaking and eating quality after cooking is very good, but there is some evidence that its shelf life is less than canned solid pack apple.

(3) *Chemistry of Processed Foods.*—Identification of the pigments of blackcurrants has been completed and the four anthocyanins present are now known to be cyanidin 3-glucoside and 3-rutinoside, and dephinidin 3-glucoside and

3-rutinoside. Behaviour of the purified pigments is now being studied under oxidizing and reducing conditions and in the presence of metal ions. It is hoped to determine the causes of colour degradation in foods pigmented with anthocyanins.

In some food anthocyanin pigments may cause pink or brown discolorations when they are formed during processing from colourless precursors known as leucoanthocyanins.

Brown discoloration occurring in commercial packs of puréed green beans has been attributed to the presence of leucoanthocyanins. Study of four varieties of green stringless beans examined at different stages of maturity established a relation between leucoanthocyanin content and discoloration during processing. Presence of leucoanthocyanins is characteristic of varieties of green beans which have coloured flowers.

(4) *Containers*.—Work continued on the problem of hydrogen swells in canned pears. Experiments have been laid down to determine the effect of: presence of spray residues on raw material; processing conditions; and tin plate used to fabricate cans. One tin-plate factor at present under investigation concerns the influence of high tin-iron alloy layer on corrosion mechanism in plain cans containing pears. In an investigation of severe pitting and subsequent hydrogen swelling in a commercial pack of prunes with cereal, evidence was obtained that the alloy layer of tin plate may be partly responsible for the abnormal corrosion with pears. The tin-plate used in this pack was typified by a high alloy layer.

Investigations have been extended to cover problems arising in flexible film packaging materials. Essential equipment for this purpose is under construction and it is planned to study and develop improved methods for the estimation of the gas permeability of completed packages.

11. Frozen Fruits and Vegetables

The Australian National Health and Medical Research Council requested the Council of Food Technology Associations to prepare codes covering quality standards and handling, with priority to be given to the latter. The Food Technology Association formed a technical subcommittee in Sydney to act on the matter and the Division of Food Preservation was invited to assist the subcommittee. A draft code has been prepared and is under consideration by the subcommittee.

To assess the conditions obtained during distribution in Australia, a survey has been undertaken in collaboration with commercial firms, to obtain product temperature histories during interstate road transport and also in retail distribution. Data gathered indicate the need for improvements in handling techniques or in vehicle and equipment design, or both, particularly in relation to retail distribution.

To ensure that research on frozen foods is properly related to the industry's needs a survey has been made of technical problems confronting processors in the main producing States.

Frozen Vegetables.—An outstanding problem with frozen foods is lack of objective methods for assessing quality and deterioration. A method is being devised to estimate the level of oxidizable volatile compounds in peas, and the correlation of volatile level with organoleptic acceptability will be determined. If an acceptable correlation is demonstrated, application of the method to other frozen foods will be examined.

Use of the maturometer for measuring maturity in peas after freezing is being studied as a further means of quality assessment of the frozen product.

In most vegetables maturity of the raw material plays a major role in determining the quality of the processed product. Investigations have been conducted on peas, sweet corn, and beans to determine optimum maturity for freezing and maturity limits within which the product is acceptable to consumer tasting panels.

A preliminary study of discoloration occurring during storage of frozen cauliflower indicated that both solar radiation and blanching techniques may be involved. An attempt is being made to determine the most effective way of overcoming the defect.

12. Dehydrated Foods

(1) *Vegetables*.—Slitting the skin of green peas before drying is known to increase moisture removal during dehydration and to result in faster and more complete reconstitution. Preparation time has now been still further decreased by precooking in steam before drying. Samples have been produced which need only 30 min soaking and 8 min cooking compared with 2 hr soaking and 15 min cooking for commercially dehydrated peas.

Tests were carried out on the differences between peas which had been water-blanched or steam-blanched before dehydration. Preliminary examination of quality assessments showed no major differences.

(2) *Fruits*.—Experiments continued on sulphur dioxide level in dried tree fruits. Data were collected on the sulphur dioxide concentrations attained within some commercial equipment, and these were compared with information derived from laboratory experiments. The problem of low retention of sulphur dioxide in dried fruit when relative humidity is high is being examined.

Attempts are being made to devise a method of determining sulphur dioxide for field use not involving distillation.

The advent of supermarkets and self-service stores in Australia has caused a serious decrease in sales of canned processed prunes. Export markets are also affected. The industry is seeking a plastic film container in which prunes can be sterilized to prevent mould development. Experiments in progress cover such aspects as types of film, heat sterilization in plastic films, and the addition of fungicides.

An electrical moisture meter for rapid estimation of water content in Tasmanian evaporated apples has been tested over several seasons and a wide range of conditions. A prototype instrument has been constructed and has performed satisfactorily under Tasmanian factory conditions.

(3) *Meat*.—Processing experiments on dried mutton and beef mince having been concluded, data are being prepared for publication, and already a number of papers have been published.

13. Irradiation of Foods

These studies are being carried out in cooperation with the Australian Atomic Energy Commission, who have provided laboratory space and radiation facilities at the Commission's Research Establishment at Lucas Heights, near Sydney. The radiation source, spent fuel elements, first became available in May 1960, but prior to this a limited number of experiments had been carried out with a 400-curie cobalt-60 source at the University of New South Wales.

Using the latter source, studies were undertaken on use of radiation to destroy fruit fly in infested oranges.

Preliminary information has been collected on the effect of radiation on development of the egg and larval stages of fruit fly and on the fruit itself, both immediately after irradiation and after storage for some weeks. Ascorbic acid content of irradiated and unirradiated fruit has been determined and compared.

At Lucas Heights over 1000 apples have been irradiated to study the effects of irradiation on the incidence of physiological disorders — core-flush and superficial scald.

21

Division of Forest Products

1. General

The Division of Forest Products was formed to carry out investigations on the products derived from Australian forestry industry, and to provide direct assistance to all concerned in the use of timber. The Division's laboratory is in Melbourne and its research is directed toward: more effective use of timber resources; reduction of waste in forest, mill, and factory; reduction of losses from decay and insect attack; and study of wood properties associated with tree breeding and silvicultural treatment to improve for timber and pulp the quality of wood produced in growing forests.

Work on timber pests is undertaken in the Division of Entomology (*see* Chapter 11, Section 15).

In view of the approaching retirement of Mr. S. A. Clarke as Chief of the Division, a Committee was set up in September, 1959, by the Advisory Council to review the future of the Division. This Committee recommended that there should be no major changes in the Division's research program.

The Division has been fortunate in securing a lease covering two properties adjoining the Division. Possession has been taken of these buildings which together increase the total ground area of the Division by 50%.

The cooperative research program arranged with the Australian Plywood Board has continued to assist technical advancement in the industry. The Board has agreed to increase its contributions for the first half of 1960–61 to £12,000 per annum. The pole investigations made in cooperation with pole-using authorities and forest services are virtually complete and the results are being analysed. Cooperative research with the financial assistance of the paper companies continued at the same level.

Grateful acknowledgment is made of help and cooperation received from the State Forest Services, the Commonwealth Forestry and Timber Bureau, the New Guinea Department of Forests, the paper companies, the Australian Plywood Board, the pole-using authorities, and all branches of the timber and allied industries.

2. Wood and Fibre Structure

(i) *Identification and Identification Methods*

This year over 550 identifications have been completed for private individuals and Government departments. Among these have been numerous specimens of driftwood from South Georgia, Tristan da Cunha, and Macquarie Island; the great majority have been identified as South American species of *Nothofagus*.

The card sorting key, based on both macroscopic and microscopic features, has not completely filled the dual role of classification at the family level and identification at the specific level; a revision has been completed and two new identification cards designed. The number of features has been increased to include those which have proved of value in identification, e.g. the type and location of crystals, and the presence of vascular tracheids.

(ii) *Cell Wall Organizations*

(1) *In Fibres and Tracheids.*—Study of ultra-thin sections has demonstrated that all layers of the cell wall are lamellated. This is consistent with previous studies, and it has been shown that the cellulose microfibrils are sheaf-like aggregates and there is a dispersion of the microfibrils about the direction of orientation. In differentiating fibres and tracheids, successive stages of elaboration of the secondary wall have been observed, and these confirm the results of purely structural observations.

(2) *In Sieve Cells of Phloem.*—As the major path of carbohydrate translocation is in the sieve cells their anatomy has particular physiological significance. In arborescent plants instances have been recorded in which the lumen of the sieve cells is extremely small, and may be almost occluded because of the great thickening of the cells walls of these elements. This thickening of the cell wall appears to decrease during senescence of the phloem. Examination in polarized light of the sieve cells of some species has shown that the cell wall consists of three layers — a birefringent outer and birefringent inner layer, separated by a broad amorphous central layer. The change in thickness during senescence is due to a decrease in thickness of the amorphous so-called "nacreous" central layer. In some cases, this layer shows a tendency to lamellation when viewed in the optical microscope.

Replica techniques show that the outer and inner birefringent layers consist of microfibrils oriented approximately transversely with respect to the cell axis, while the nacreous layer appears amorphous. From ultra-thin sections it was apparent that the nacreous layer contains both microfibrils in a loose network and amorphous components. The fact that these lamellae are less obvious in thicker sections suggests that some anastomosing between them may occur in a plane perpendicular to the cell surface.

Preliminary work to determine the chemical nature of the nacreous layer has been carried out by studying the hydrolysis of the resistant fraction of the cell wall and subsequent chromatographic examination of sugars in the hydrolysate.

(iii) *Microscopy of Semi-Chemical and Mechanical Pulps*

This work has been extended to include neutral sulphite semi-chemical and groundwood pulps. In the former, separation has been observed between fibres as was the case with other semi-chemical processes involving high temperatures. In the manufacture of groundwood there is no preferential region of separation and, as a result, the pulp is composed of a morphologically heterogeneous collection of fibre fragments. However, differences in pulp fragment structure from woods of different grinding qualities have been observed. Attempts are in progress to relate such differences to the quality of the original wood. From these results and from investigations of fine structure it has been concluded that the region between the fibres, and the boundary between outer and middle layers of the secondary wall, are of particular significance. Chemical treatment involves breakdown between the fibres, whereas mechanical processing results in rupture of the cell wall. In the preparation of semi-chemical pulps the interplay of these factors determines the nature of the breakdown of the wood following a particular pattern of processing.

(iv) *Wood and Bark Extractives*

(1) *Site of Formation.*—Chromatographic examination of extracts of several species has shown that polyphenols in the cambium differ in some respects from those in wood and bark. Polyphenols from the latter also differ from each other. Polyphenols appear to be synthesized *in situ*. The major compounds which differ in the various tissues are being isolated to permit further study of metabolic processes involved in heartwood formation. An examination commenced of factors which could control the amount of polyphenols formed. One of these is the relationship of available volume of cell lumen to extractive content.

(2) *Type of Compound Formed.*—Kinos from many species of *Eucalyptus* and other genera have been examined. In all cases they contained large amounts of leucoanthocyanins, and with two exceptions, phloroglucinol was obtained after strong acid treatment. Polyphenols in uninjured cambium examined are markedly different from those in the kinos produced by the same species and underlying causes for these differences are being investigated.

(3) *Components Characteristic of a Species.*—Chromatographic examination has shown that four of the five New Zealand *Nothofagus* species can be readily identified by the chemical components present. Extractives of several *Eucalyptus* species and acid degradation products from their kinos show that these species can be divided into groups, and in some cases it may be possible to identify a species in this manner.

(v) *Assessment of Wood Qualities for Tree Improvement*

A procedure has been developed whereby a number of selected trees from plantation-grown conifers can be examined anatomically to assess wood quality. Such features as fibre length, micellar angle, basic density, percentage of late wood, incidence of compression wood, and spiral grain, have been determined in the wood from successive growth rings from the pith in samples taken at approximately

3 ft 6 in. above ground level. Study of interrelations between these features and between selected features and such properties as longitudinal shrinkage and crushing strength, has provided valuable information. To date this work has been carried out on specimens from selected trees of *Pinus elliottii*, *Agathis robusta*, and *Pinus radiata*. The degree of heritability of such features as fibre length and basic density is being investigated.

(vi) *Anatomical Investigations*

Publication of data on members of the Burseraceae from the south-west Pacific area has been delayed because of receipt of more material from the Philippines and west New Guinea. In the meantime a summary of the distinctions between the major groups of the genus *Canarium* based upon wood anatomy studies in this Division has been used in a Dutch publication on the taxonomy of this genus. Work is continuing on the timbers of the Sapindaceae and Sapotaceae occurring in the same area.

3. Wood Chemistry

(i) *Artificial Lignin*

Use of potato parenchyma in place of *Avena* coleoptiles has given larger amounts of artificially lignified tissue for chemical investigation. Lignin isolated by various methods always contained nitrogen. That isolated by milling in toluene and extracting with aqueous dioxan exactly as used for the isolation of "milled wood lignins" had the lowest nitrogen and highest methoxyl content and its composition was close to that of softwood lignin. The yield, however, was very low. The infrared absorption spectrum resembled that of softwood lignin but showed an extra band. Vanillin was produced on oxidation but only in about a quarter of the yield obtained from softwood lignin. Artificial lignin thus appears similar to but not identical with natural lignin. Investigation of its mode of association with nitrogen may give valuable leads to the nature of natural lignification processes which also seem to involve nitrogen.

(ii) *Carbohydrate Investigation*

(1) *General.*—Carbohydrates present in the cambial zone of *Eucalyptus regnans* are being investigated. Sections of *E. regnans* wood have been hydrolysed at 75°C with buffer solutions of pH 3.5 and 10.5; results indicate that hydroxyl ions are about 1000 times as effective as hydrogen ions in causing scission of interfibre bonds (presumed ester bonds).

Carbohydrates of *Calycanthus* species and of *Ecklonia radiata* have been studied; major easily extracted compounds of the latter species have been characterized as alginic acid, mannitol, laminarin, and fucoidin — these carbohydrates have also been examined with respect to seasonal variation.

(2) *Hydrolysis of Cellulose in the Presence of Pentosans.*—It has been suggested by Roudier (Paris) that cellulose and xylan in straw pulp may exert a mutual protective action during acid hydrolysis. This hypothesis has been

investigated by hydrolysing wheat straw, barley straw, and wood (*E. regnans*) holocelluloses; the reduction in molecular weight of the cellulose fraction is less than when the pentosan content is first reduced to *c.* 6% by extraction with 5% alkali. Cotton also shows a higher apparent rate of degradation; this appears to be connected with structural features which lead to a greater retention of material of low molecular weight than in the case of wood and straw celluloses. Uncertainties which emerge from interpretation of these new data are sufficient to cast doubt on the xylan protection theory.

(3) *Infra-red Spectra of Polysaccharides.*—A detailed study has been made of a wide range of polysaccharides, with particular reference to cellulose and related compounds. The object of this work has been to arrive at a full assignment of the absorption bands, and apply this information to elucidate the mechanisms of various physical and chemical transformations induced in cellulose and hemicelluloses under conditions encountered in processing these materials.

(iii) *Pulping Investigations*

Young trees of three Western Australian eucalypts, *E. diversicolor, E. marginata,* and *E. calophylla* gave good yields of chemical pulps with good tearing strengths and other properties not much inferior to those of commercial eucalypt pulps. Old trees gave a poorer grade of pulp. Neutral sulphite semi-chemical pulps also showed satisfactory strength properties but the cold soda pulps were poor. Two New Guinea species, *Anisoptera polyandra* and *Pasania* sp., gave good yields of chemical and semi-chemical pulps of which those from the former had better strength properties.

(iv) *Influence of Fibre Morphology on Pulp Strength*

The importance of fibre length has been confirmed. Experiments in which factors other than cell length have been kept constant have shown how tearing strength increases with increase in fibre length. Other properties are increased but to a lesser degree.

Numerous woods of the Myrtaceae in which cell length and the cell length/diameter ratio varied were pulped under comparable conditions. Variations in the ratio from 35 : 1 up to 70 : 1 did not influence pulp strength properties in any way other than expected from increases in length.

Early and late wood from several growth rings of a specimen of *Pinus taeda* were pulped separately, and the pulps subsequently blended in various proportions before beating. Thick-walled late-wood fibres definitely assist tearing strength but all other properties decrease with increase in the number of such fibres in the mixture.

(v) *Dimensional Stabilization of Paper*

Recent investigations demonstrated that it is impossible to curtail or eliminate the embrittlement which normally accompanies dimensional stability achieved in paper by either thermal reaction or cross-linking with formaldehyde. Restraining forces built into paper to endow it with dimensional stability are also responsible for its embrittlement.

(vi) *Papermaking Properties of Dense Eucalypt Woods*

Previous work sought to modify the thick walls of fibres of dense eucalypt woods to create more and better interfibre bonding opportunities. Recent investigations, however, suggested that pulps having both greater strength potential and response to beating, may result from subjecting freshly cut green wood to milder pulping conditions than those usually applied.

(vii) *Influence of Pulping Method on Paper Properties*

Experiments have been carried out to determine the effect on paper properties of cooking cotton cellulose and delignified wood pulps, both alone and in the presence of other materials derived from wood and holocellulose, which are usually present in cooking liquors. The fact that unbeaten sulphate pulps show lower tensile and bursting strength than sulphite pulps is considered to be related to a lower concentration of accessible polysaccharides in the surface regions of the fibre. Re-deposition of xylan in the manner suggested by Swedish workers, which involves some degree of crystallization, can account for these effects.

(viii) *Physical Behaviour of Paper Pulps*

Work continued on flow of pulp suspensions and drainage of water through fibre pads. In studying the permeability of a compressible medium such as a laterally isotropic assemblage of cellulose fibres in the initial stages of paper formation, it is necessary to distinguish between fluid pressure and the pressure component producing deformation. Relationship between this rheologically effective pressure and porosity providés a partial description of the response to stress of the draining fibre pad. The rheological behaviour has been studied from drainage observations in an apparatus in which pressure and flow rate can be controlled. If the specific surface is constant for a given pulp at a given stage of beating, it becomes a constant in the Kozeny-Carman and drag equations. The effect of cyclic application of pressure on the apparent drainage resistance of fibre pads had also been studied, and irreversible hysteresis effects have been observed which apparently arise from incipient bonding.

4. Timber Physics

(i) *Sorption Studies*

Investigation has continued of the kinetics of sorption of water vapour by wood. Measurements of rate of sorption by specimens of *E. regnans* from 20 microns to 3 mm in thickness confirmed the dual nature of the sorption process. At low relative vapour pressures, stress relaxation appears sufficiently fast for diffusion of moisture into wood to be the rate-controlling mechanism for even the thinnest specimens. At high vapour pressures or where very small vapour pressure changes occur, relaxation of stress becomes much slower than diffusion, and moisture content equilibrium is attained equally slowly in specimens of a wide range of thickness.

Further confirmation of these conclusions was obtained from timbers of widely differing density. Longitudinal sectioning of the wood to thicknesses of less than the mean fibre diameter led to increases in equilibrium moisture content. This was attributed to partial removal of restraints to swelling, because the effect was much greater in high density timbers with thick cell walls than in low density timbers.

(ii) *Rheological Characteristics*

(1) *Effect of Moisture Content Changes*.—Study of the effect of changes of moisture content on deformation in loaded specimens has continued using beams of 1 in. square cross section and also, more recently, very small specimens in which more uniform and rapid changes of moisture content could be attained. Centrally loaded beams of both sizes showed progressive increases in total deformation with each cycle of moisture content change, although during each moisture content increase, except the first in initially dry material, a decrease in deformation occurred. Increase in total deformation after each cycle was greater for large moisture content changes than for small changes.

Tests on small specimens under tension in the tangential direction showed increases in tangential movement during moisture content changes, but here the increase was largely confined to the first moisture content change after loading.

(2) *Wood Under High Stresses*.—Studies of non-linear creep behaviour in wood in bending at high stresses have been extended to hoop pine. In addition to tests at ambient temperature, others have been carried out on both hoop pine and mountain ash at 20°C above ambient and on mountain ash at 35°C above ambient. Non-linearity of behaviour in mountain ash was found to be more pronounced in material of Tasmanian origin than in Victorian. Hoop pine behaved similarly to Tasmanian mountain ash, but the magnitude of creep was considerably greater in hoop pine under all conditions of test. However, the experimental constants varied surprisingly little from species to species. Increased temperature markedly increases both total and recoverable creep.

A series of creep tests was also carried out on mountain ash in shear. Here again most of the constants were similar in value to those for bending, an exception being the size of the flowing molecular segment which appears to be larger for shear. At constant rate of straining, energy considerations suggest that units of about the size found by other workers for the crystalline region move relatively to each other in instantaneous elastic deformation.

Delayed elastic strain in wood appears to be primarily the result of changes in intrinsic energy rather than of changes in degree of order; that is, it is glass-like rather than rubber-like.

A small automatic testing machine has been developed for slow cyclic loading tests on wooden beams. It produces sine wave stressing or straining with a frequency variable from about one cycle per minute to one cycle in several hours. Some tests have been made on hoop pine specimens and are being analysed to correlate the results with those of vibrational tests on the one hand and creep and relaxation on the other.

(3) *Vibrational Properties of Wood*.—An automatic instrument has been built for measuring the dynamic modulus and damping capacity of wood at audio

frequencies to an accuracy of about 2%. Preliminary measurements have been made on the dynamic properties of hoop pine.

(iii) *Instrumentation*

Increased use of electrical resistance strain gauges, not only for strain measurement but also for control of automatic testing machines, has led to a progressive development in the bridges associated with them. These bridges have almost exclusively been based on use of transformer ratio arms which have several other important advantages for this work besides accuracy and long-term stability.

5. Timber Mechanics

(i) *Properties of Timbers*

Mechanical testing has been completed of green material from nine trees of wandoo, eight trees of blackbutt, and seven trees of tuart from Western Australia. These tests have provided more adequate information than has hitherto been available on these species and has enabled the timbers to be classified more satisfactorily into suitable strength groups for structural design purposes.

Tests are continuing on the dry material from a number of species from the eastern States.

To assist in choosing suitable Australian timbers to replace imported species, and to help in the efficient use of imported timbers, a publication has been prepared giving in tabular form the more important structural and other properties of 250 overseas timbers.

(ii) *Silvicultural Tests*

Further tests have been made on a number of trees of radiata pine. Statistical analyses of these and earlier results have been made to assess means of estimating the strength of the wood from such properties as density, age, and fibre length. Within any particular tree, satisfactory estimates can be obtained, but only from the relationship established between strength and these other factors for that tree. It has not yet been found possible to predict with accuracy the strength of the wood in a tree, from the overall relationship established on a large number of trees.

(iii) *Timber Engineering*

(1) *Structural Design.*—Many requests for assistance in timber design continue to be received, and designs have been prepared for a number of structures, several of which have been constructed and proof-tested. An investigation commenced to examine the possibility of using models to study the characteristics of full-size structures, particularly trusses with spans greater than 60 ft.

Preparation of a table of sizes of round timbers for stringers in highway bridges is nearing completion.

A study is being made of the effect of concentrated loads on a wooden floor system, with particular regard to distribution of load between individual joists. For the simple case of a single floor board distributing the load over several joists, results agree very well with theory. Load distribution, when the floor is completely covered with boards, is currently being studied.

(2) *Nails.*—A detailed study was made of the relations between impact and static withdrawal resistance of nails, and dependence of these properties on length and diameter of nail.

A number of joints in dry radiata pine and in green messmate stringybark have been erected under test loads as part of the study of long-duration loading of nailed joints.

(3) *Columns.*—Six more model columns were erected for test during the year and four others failed. Two of the latter were of Douglas fir and had sustained a load equivalent to 60% of their short-time failing load for a period of 5 years. Both of these were of slenderness ratio $L/d = 10$ and had been kept green throughout their test life. A third failure was of a yellow stringybark column which had been kept green under a 50% load for 5 years. The remaining failure was a green mountain ash column which had sustained a 50% load for $8\frac{1}{2}$ years.

(4) *Scantling.*—To widen the sampling of radiata pine scantlings, 20 logs of Victorian-grown *P. radiata* were converted into 4 by 2 in. scantlings and these, after drying, were tested in four-point bending. On analysis, the results were compared with those previously obtained with South Australian–grown material in regard to the efficacy of the Standards Association grading rules for this timber. Whereas the grading rules were reasonably effective in eliminating low strength pieces in the South Australian parcel, they were not so effective when applied to scantlings from Victorian-grown trees. Investigation is proceeding to find some method by which grading rules may be made more efficient.

(5) *Poles.*—With the testing of 24 radiata pine poles, all the work planned on green poles has been completed. A number of dry poles with their butts resoaked to simulate service conditions have been tested. To determine the influence of checks on pole strength, 19 hardwood poles, rejected from service because they contained large drying checks, were tested after the butts had been resoaked.

The investigation of the effect of preservative treatment on pole strength has been commenced, 12 poles of radiata pine treated with water-borne salts having been tested, and a further 12 poles treated with creosote prior to testing.

Radiata pine round posts for farm fencing are being tested to determine the effect of mechanical debarking on bending strength.

6. Timber Preservation

The volume of advisory work has continued to increase, and much time has been devoted to problems associated with design of plants and development of the pressure treatment industry in Australia. An important development has been establishment of a commercial high-pressure plant for treatment of karri crossarms in Western Australia using a preservative oil at a pressure of 1000 lb per sq. in.

(1) *Field Tests.*—The long-term program of rail sleeper tests, which has been a major project for several years, has now reached the stage where all treatments have been completed, and tests comprising many thousands of sleepers have been placed in service in all States.

A new test has been prepared to determine the effectiveness of various preservatives when exposed to a high marine borer hazard. This test has been installed in the Brisbane River, Sydney Harbour, and two ports in Western Australia — Kwinana and Port Hedland.

(2) *Diffusion Treatments.*—Tests have continued on the borofluoride-chrome-arsenic preservative patented by the Division for dip-diffusion treatment of green building timber. This preservative has been reformulated to produce a dry stable powder suitable for commercial manufacture and a further patent application has been lodged.

A survey has been made to determine the need for preservative treatment of building timbers in Papua and New Guinea and the relative suitability of pressure and diffusion treatments for this purpose. Because of the difficulty of drying timber under tropical conditions, and the impermeability of the heartwood of many species to pressure treatment, dip diffusion has been recommended as suitable provided treated timber is reasonably protected from leaching. Penetration obtained by the dip-diffusion treatment in various tropical hardwoods is being investigated.

(3) *New Preservatives.*—Investigation of distillate oils from brown coal tar produced by the Lurgi gasification process has shown that the 200–300°C fraction, used as a "wash oil", has satisfactory toxicity but insufficient permanence to be comparable to Australian standard creosote oil. A higher temperature fraction has given promising results, but there are practical difficulties in handling the residue.

Distillation of wood tar from the charcoal-iron plant in Western Australia yielded up to 50% of a heavy oil of high phenolic content, which has given good results in laboratory tests. It is compatible with bituminous coal tar creosote and with mineral oil.

(4) *Durability of Heartwood.*—Studies of decay resistance of durable eucalypts have shown that toxic extractives, identified as polyphenols, are mainly responsible, but that in some species there are secondary factors believed to be chemical rather than anatomical. In tallowwood, termite resistance is caused by repellent compounds which are not the same as those conferring decay resistance.

Studies of decay resistance in teak have shown that most of the variation within and between trees can be accounted for by a multiple regression equation combining distance of specimen from pith, age of tree when specimen wood was formed, rate of growth, and age of tree when felled. No factor was of predominant importance.

(5) *Mycological Studies.*—Laboratory evaluation of preservatives continued, and facilities were expanded to permit tests in accordance with standard A.S.T.M. methods.

Screening tests on agar medium of preservative-resistant species of *Poria* showed that six out of 13 strains of *P. vaillantii*, and one out of five strains of *P. sericeo-mollis*, were highly tolerant to both copper and arsenic. No tolerant strains have been found yet in *P. vaporaria*, *P. xantha*, or *P. weirii*. All tolerant strains were comparatively sensitive to zinc in agar tests.

Satisfactory techniques for laboratory production of soft rot have been developed. Fungi isolated from soft rot in cooling towers are being studied for wood-destroying ability, preservative tolerance, pH, and aeration requirements. Experimental test trays of various untreated timbers have been placed in 25 cooling towers throughout Australia for annual observation of soft rot development.

7. Timber Seasoning

(1) *Drying Studies.*—Presteaming was further developed and established in industry as a drying accelerator for difficult ash eucalypt timbers. Field tests demonstrated a reduction of 20% in time. Seasoning losses in highly check-susceptible messmate stringybark were significantly reduced. Predrying schedules were re-examined and conditions established to give a further 5% saving in drying time. A short air-drying period before predrying was shown to be highly effective.

Studies to accelerate the drying of poles, posts, and sleepers to a condition suitable for preservation treatment were continued. Kiln drying of ash eucalypt sleepers from 125% moisture content to 34% at ½ in. depth from surface required 40 days. A plant was installed for Boultonizing, steam-and-vacuum seasoning, and superheated steam drying these timbers.

Chemical seasoning greatly improved the drying behaviour of sawn timbers from young trees of mountain ash. Use of stack models in studies to improve drying rates in air seasoning yards was examined. Stack weighting at 140 lb per sq. ft. plus concentrated end loadings of 300 lb reduced twist and bow in radiata pine structural timbers by 48 and 28% respectively. Little reversion occurred.

(2) *Collapse and Recovery.*—Interaction was examined between collapse, shrinkage, drying conditions, and the anisotropy of wood. Collapse intensity was markedly influenced by drying stresses; the characteristic concavity of collapsed surfaces after drying was established as mainly a visco-elastic Poisson effect due to restraint in width caused by tension set. An equation was established expressing collapse at a given temperature as a function of surface tension and the structural and rheological properties of wood. Collapse activation energy was tentatively established as approximating a few kilocalories per mole of bonds broken.

Steam pressure in the range of 25–100 lb per sq. in. was shown to inhibit recovery by reconditioning; the effect increased with increased pressure and time to a stage where additional collapse was induced. Indications were obtained that a short heating at high temperature before reconditioning increased recovery. Field results showed improved recovery by wetting steam expanded from high to low pressure for reconditioning purposes.

(3) *Dimensional Stabilization.*—Work commenced with polyethylene glycols, silicone, phenol formaldehyde, sucrose, glucose, and urea as possible dimensional-stabilizing media for sawn timbers of eucalypt species. For the sugars and urea a 33% solution strength reduced total shrinkage by half; anti-shrink effects increased steeply with further increase in concentration.

(4) *Moisture Movement and Diffusion.*—Development commenced of a water vapour diffusion apparatus. Diffusion of ions and electrons in an electrical field

in the presence of an exchange reaction was considered theoretically. The steady-state distribution was shown to be given by modified Bessel functions of the second kind, the argument depending on charges, mobilities, diffusion coefficients, and rate constants.

(5) *Equilibrium Moisture Content.*—An analysis commenced of meteorological and wood moisture data from specimens of eight species in three thicknesses at 12 key centres in Australia and New Guinea. Close correlation with mean wood isotherms in the 50–80°F range was found except at high moisture contents. An equation giving good correlation with observed moisture content values was established for $\frac{1}{4}$ in. thick material, but data for $\frac{3}{4}$ and $1\frac{3}{4}$ in. material are as yet insufficient. The Australian zones with greatest seasonal equilibrium moisture content (e.m.c.) range proved to be the central and south-central areas; sites with highest e.m.c. values were Melbourne and Hobart, and that with lowest was Alice Springs.

A supplementary indoor e.m.c. study was extended to determine the effect of typical wood finishes on moisture and dimensional change.

(6) *Industry Assistance and Drying Equipment.*—Nine cooperative seasoning research studies were established with industry. Activities concerned with improving technical standards and seasoning technology in industry were given special attention. Advice and designs on plant layout, and stacking and handling equipment, were prepared for 26 firms; performance tests were continued to improve inefficient kilns, and special consideration was given to dryer instrumentation.

Work continued to reduce structural deterioration of reconditioning chambers subject to attack by wood acid volatiles at high temperature. Promising results were obtained with a vibrated dense concrete, air-entraining agents, and low water-cement ratios.

Designs for dryers and reconditioners for sawn timber, veneer, round timbers, and associated equipment were prepared for 34 firms and research organizations in Australia, New Guinea, New Zealand, British Borneo, India, Fiji, Malaya, South Africa, U.S.A., Denmark, Argentina, and Venezuela. Assistance was given commercial kiln construction specialists on technical aspects of heating and air flow.

8. Plywood

(i) *Veneer Cutting*

Species investigations included coachwood, hoop pine, *Celtis nymannii*, and *C. latifolia*. The multiple-knife technique was used to examine the influence of knife bevel on quality and curl of hoop pine veneer. Of the four knife bevels examined 23° gave the smoothest surface combined with resistance to knife gapping. Varying the horizontal nosebar settings showed that most curl occurred at the smaller nosebar gaps. Conditions required for peeling very thin veneers were studied. Special gears were made to enable peeling down to a thickness of 0.004 in. Hoop pine veneer of this thickness was peeled satisfactorily but similar peeling tests of coachwood were less promising. However, coachwood was peeled at 0.007 in.

thickness quite readily. The effect was studied of pre-loading the lathe pressure bar-knife carriage assembly on the time required to attain nominal veneer thickness.

(ii) *Veneer Drying and Wood-Water Relationship*

Tests of the new laboratory experimental dryer were commenced. Following preliminary air-flow studies, low pressure steam was connected, and at drying temperatures in the vicinity of 150°F dry bulb and 100°F wet bulb the quality of experimental veneer was satisfactory. The efficiency of commercial drying equipment was studied, including two roller-type dryers using both convective and radiant heating, two roller dryers using convective heating only, and three C.S.I.R.O. screened dryers. Surveys of temperature and humidity, and tests of drying uniformity, were made.

A study of moisture resorption in $\frac{1}{16}$ in. karri veneers showed that moisture regain from oven dry to 10% could be effected in 16 hr under 12% e.m.c. room conditions, in 1 hr at 160°F dry bulb and 5°F wet bulb depression, and $\frac{1}{2}$ hr in saturated conditions at 212°F. The effect of temperature on resorption time of thicker veneers became apparent in the case of $1/10$ in. karri in which regain of moisture content from oven dry to 10% under 12% e.m.c. conditions took three times longer than for $\frac{1}{16}$ in. veneers; at elevated temperatures (160 and 212°F) the time required was only about 50% longer.

Shrinkage of hoop pine veneers at veneer moisture contents within the range 0–17% was greatly reduced by treating at 100°C with a solution of wattle tannin extract followed by a cold treatment with formaldehyde solution.

(iii) *Gluing*

(1) *Tannin Formaldehyde*.—The effect of inorganic salts on the gelation time of wattle tannin formaldehyde was investigated. Soluble salts of mono-, di-, and trivalent metals were tested, and at a concentration of 10% of the dry tannin many reduced gelation time substantially. Several were tested at lower concentrations and were effective at less than 2% concentration. Effect of pH on gelation time and the formaldehyde absorption under various conditions were also studied. Adhesion tests were made using wattle tannin-formaldehyde adhesives with and without added fortifying resin. An unfortified tannin adhesive could produce a boil-proof bond with some veneer species, but with other species fortification was necessary to give resistance to the 72 hr boil test. Tests of unfortified wattle tannin adhesives as bonding agents for chip board were carried out both in the laboratory and under commercial conditions. Results of both series of tests were very satisfactory and further large-scale tests have been planned.

(2) *Phenol Formaldehyde*.—On continuing investigations of the effect of boron on phenol formaldehyde resins, two commercial adhesives were studied. Rate of gelation of both preparations was affected by small percentages of borax. Work continued on the formulation of resorcinol phenol formaldehyde adhesives, with particular reference to the effect of the ratio of formaldehyde to other constituents on gelation time, storage life, and adhesive properties.

(3) *Urea Formaldehyde.*—Carboxymethylcellulose (CMC) wheaten flour and water in various combinations were used to extend a melamine-catalysed high-solids urea formaldehyde resin. Results showed that the effects of CMC extension and flour extension on wet and dry strength of hoop pine test panels were similar.

(4) *Gluing Properties of Wood Species.*—Improved results in the gluing of karri were obtained with a resorcinol formaldehyde adhesive compared with phenol formaldehyde. Dry and boil tests gave high strength and wood failure. The effect of viscosity of a phenolic adhesive on bond strength with karri, and the gluing properties of red gum and tallowwood, were also investigated.

(5) *Glueline Failure.*—Study continued of factors affecting the surface condition of veneers leading to low bond strength. Influence of temperature appeared to be slight, but there was a significant effect of veneer moisture content previous to inactivation, shear strength decreasing with increasing moisture content. As observed previously, sanding appears to overcome the effect of inactivation. Preliminary experiments were made on a simple sonic method for locating areas of non-adhesion in plywood panels.

(6) *Weathering Tests.*—Weatherometer tests of phenol formaldehyde resin bonded coachwood and hoop pine plywood were concluded after exposure for 15 months. Results indicated the apparent over-riding importance of species on durability of bond; all coachwood panels delaminated completely, but hoop pine panels did so to a small extent only. In both species bonding of boron immunized veneers was weaker than untreated ones. A significant effect of pressing time on durability was not established.

All pigmented paint coatings on both untreated and overlaid plywood surfaces on exposed panels on the Division's lecture room are intact after 3 years' exposure; but the most durable of the clear coatings tests, a polyurethane, is at the end of its useful life after 2½ years. Further deterioration took place in panels covered with unprotected kraft paper, and the phenolic glue film beneath shows considerable splitting. In the test of aluminium clad roofing panels, considerable delamination occurred in the metal bond of one panel in which the aluminium foil was etched before gluing with a casein latex adhesive.

(iv) *Miscellaneous*

Experiments on a method of removing end splits have been initiated. Panels after sanding showed a remarkable improvement, in most cases the splits being completely closed or rendered almost invisible. Whether such treatment is likely to result in future deterioration is not known at this stage.

Experiments were conducted to determine the minimum bending radii obtainable with plywood grooved on one side with multiple parallel trenches. Tables have been compiled of minimum radii for dry specimens, and for those soaked in boiling water prior to bending, all specimens having been trenched to a residual thickness of between $\frac{1}{16}$ and $\frac{3}{16}$ in. The influence of moisture content, pretreatment, and spacing of grooves was also studied. Except when the trench reached or approached the glueline closely, there was little difference between minimum radii of grooved plywood and of plywood from which material between the trenches had also been removed.

Permanent deformation in veneers strained along the grain was investigated at 120, 150, and 180°F. Desorbing conditions from 17 to 5% moisture content caused greater permanent deformation than constant moisture content conditions. Permanent deformations obtained during drying from 17 to 5% moisture content at 150°F represented 95% of the preload deformation. A further 35% increase in permanent deformation was obtained by increasing the preload stress.

Study of the straightening of buckled $\frac{3}{16}$ in. plywood showed that plywood also can accept sets under changing moisture content conditions. A treatment for removing twist from plywood panels is being developed. This treatment resulted in complete removal of experimentally induced distortion, and is an effective application of the results of the basic experiments on set and deformation.

Some 940 inquiries were answered covering most processes of plywood manufacture and also aspects of plywood utilization and general adhesion problems. Officers spent a total of 106 man-days on visits to plants in the eastern States outside Victoria and in South Australia, giving assistance in peeling, veneer drying, and gluing problems of the industry. Six-monthly reports were prepared for the industry, and assistance was given in drafting revised specifications for plywood.

9. Utilization

(1) *Timber Uses.*—Information was supplied on the suitability of timbers for 123 uses and advice given on the properties and uses of 144 species.

(2) *Manufacturing Processes.*—Sawmillers were assisted in the design of new and redesign of existing sawmills and given information relating to techniques and machinery suitable for particular steps in production. Plans were prepared for five sawmills, three planing mills, two joinery works, and two distributors' yards, and advice given at various stages in development of other plants.

Technical factors affecting economic manufacturing of wood wool, wood flour, and other products from wood were reviewed for inquirers.

(3) *Saws.*—Thin saws that show promise in ash eucalypts were studied in dense timbers in Queensland to ascertain their effectiveness at different rim speeds.

Results so far obtained indicate that under some conditions gauge reductions may be practicable, even with such dense species as the ironbarks. Deflection of saw teeth and pattern of stresses caused by lateral forces were studied in the laboratory. A specially designed tooth has been shown to be not only stiffer against deflection, but also to have a lower maximum stress. Consideration was given to measurement of tension in circular saw blades. Relations between profile details, wear, energy, and feed speeds were studied.

Ten chain saws of modern design imported by the Australian timber industry were tested, in collaboration with the Forestry and Timber Bureau, in forests of light eucalypts, heavy eucalypts, and small pines. Data on production rate and other characteristics were recorded and analysis is proceeding.

(4) *Residue Utilization.*—Finger-jointing as a means of utilizing short lengths and of improving grades continued to receive attention. Advice given on techniques, recoveries, and quality control led to further commercial applications. In the laboratory the effects of profile on strength were further investigated, and the rate of wear of cutters that produce joints of high strength was studied when tips were tool steel and stellite. A procedure was developed for reducing the moisture content of profiled surfaces in otherwise green scantling for the period requisite for gluing.

Inquiries were answered on particle resin board manufacture, and on the use of sawdust as fuel, soil improver, heat insulators, and other miscellaneous purposes.

(5) *Standards.*—Collaboration with the Standards Association of Australia continued. Standards concerning parquetry blocks, laying of parquetry, and wooden cheese crates for export were published; grading rules for decking and structural timber were revised and proof issues circulated for public review; standards were reviewed for radiata pine sawn and milled products and for hardwoods of south-east Australia; specifications for sleepers were drafted; and preliminary consideration was given to specifications for timber for small craft. Comment was submitted on specifications from Standards Institutions in Britain, India, New Zealand, and South Africa.

(6) *Liaison.*—A confidential report concerning equipment requested from Australia under the Colombo Plan for logging, sawing, and processing was prepared for the Department of External Affairs after investigations in Ceylon. Interest in saw design work was indicated by an attendance of 100 timber men at a lecture given on saw studies in Brisbane.

22

Soil Mechanics Section

1. General

Research in the Soil Mechanics Section at Syndal, Vic., embraces the soil aspects of two principal fields of civil engineering research — building and road construction. The Section works in close collaboration with the staff of the Division of Soils in Adelaide, and a branch of the Soil Mechanics Section is stationed in the Division of Soils. Similarly close scientific contact has developed with the Civil Engineering Department, University of Melbourne, which occupies jointly with the Soil Mechanics Section the laboratory at Syndal.

The Section's principal objectives for the current year have been recruitment of staff and procurement and installation of basic testing equipment for research on soil mechanics and stabilization. Although the major emphasis in research has been placed upon studies of building foundations and pavement subgrades, investigation of landslips now being undertaken in Tasmania has outlined the possibility of greater appreciation of problems associated with stability of natural slopes.

The Section has continued to participate in the lecture and post-graduate research program of the University of Melbourne.

Satisfactory liaison has been established with the Imperial College, London, largely through a studentship project undertaken by an officer of the Section. With the attendance of the Officer-in-Charge at the recent Pore Pressure and Suction in Soils Conference held in London, closer collaboration has been achieved with similar institutions in the United Kingdom and elsewhere in Europe.

2. Foundations

(1) *Shallow Foundations.*—Investigations and observations of domestic type buildings on clay soils in a winter rainfall–summer drought climate at Elizabeth, S. Aust., have been completed and the results published.

A further investigation is in progress on an area of several square miles at Christies Beach, S. Aust. An interesting outcome of both of these investigations is the demonstration that the foundation characteristics of these soils are dependent less upon the existing moisture regime, than on the moisture regime which can develop in a mature suburban environment.

At Elizabeth, a tendency has been predicted for a progressively drier soil environment with the growth of the town. This has been confirmed by observation, and increasing foundation difficulties can be anticipated associated with volume change as time goes on.

At Christies Beach, where the soils are initially comparatively dry, the probability of the development of a perched ground water-table has been recognized. The consequent problem of extremely low bearing capacity in the saturated loose calcareous surface horizons is being examined.

Similar investigations have been undertaken on a smaller scale in the Wimmera area of Victoria on a heavy clay soil in a winter rainfall zone. Study of the problems of shallow foundations on clay soils in a summer rainfall zone is now planned for 1960–61. Areas for these investigations have been selected in central Queensland.

(2) *Deep Foundations.*—Foundation investigations have been undertaken for a number of major building projects principally in South Australia and Tasmania. Apart from procurement of practical information, a major purpose of these investigations has been study and development of techniques for soil sampling. The experience gained in these investigations has been transmitted to an increasing group of soil mechanics consultants throughout Australia.

A long-term research program has commenced to provide a comparison of computed and actual settlements of buildings. The calculations of settlement are based on several alternative techniques for the measurement of the modulus of compressibility of the soils which are usually not fully saturated. It is hoped to establish an appropriate set of testing and computation procedures to apply to such unsaturated soils.

3. Subgrade Moisture

In collaboration with pedologists from the Division of Soils, problems of moisture movement in pavement subgrades are being investigated with funds allocated from the major State road authorities.

Following selection of sites representing most of the important soil types and climatic regions in Australia, equipment has been designed and techniques are being developed for an early start on the field program.

Much of the previous equipment used for moisture studies has been modified and redesigned. Although this has delayed the project for several months, adoption of new techniques and equipment should expedite the further stages of the experimental program.

4. Soil Stabilization

It has been necessary, during the last 12 months, to review the original terms of reference for this project. Unfortunately, progress has fallen behind expectations, owing to problems of space, equipment, and lack of funds. As a result, it was not possible to maintain a complement of suitably qualified staff.

An amended research program has been devised to meet the new circumstances. As before, the project hinges on applicability of the pedological classification of soils to this engineering form of land use. Increased emphasis is to be placed upon fundamental long-term studies of soil stabilization principles.

5. Basic Soil Properties

Study of the engineering characteristics of unsaturated soils has been a feature of the Australian soil mechanics research program for many years. This has been due principally to the soil conditions encountered as a result of the semi-arid nature of much of the Australian environment. During the past year it has proved possible to express these engineering characteristics in terms interpretable to other soil mechanics groups, and measurable in appropriate laboratories. Agreement has been recorded between parallel work in Australia and other countries, notably England and South Africa, and a common approach developed to measurement and notation.

6. Stability of Natural Slopes

At the request of the Tasmanian Government and the Launceston City Council, a comprehensive study of landslip investigations is being undertaken in Launceston and Bell Bay. A series of landslips has occurred on the outskirts of Launceston city, and the possibility of further slips both in Launceston and Bell Bay is being investigated.

A sampling program, together with laboratory analysis and engineering analysis of data obtained, will require 12 months to complete.

Results of current geotechnical surveys suggest that, in major zones of instability, movements of discernible or damaging magnitude occur only in minor areas. Ample morphological evidence is, however, available to suggest an almost universal pattern of active slipping within the present geological period. The critical requirement in such landslip investigations is definition of a time scale for movements of various magnitudes, rather than determination of ultimate slope stability. The problem of calculating these rates of movement has not been solved, but a survey procedure to define actual movements has been advanced, and this will be implemented during the coming year.

23

Division of Building Research

1. General

The Division of Building Research is the main centre within C.S.I.R.O. undertaking research relating to the building industry. The primary responsibility of the Division is long-term research, and the major part of the Division's activities is devoted to investigation of building materials. Research is also undertaken on architectural acoustics and the thermal characteristics of buildings.

Building research in Australia is spread throughout a number of establishments. At the Commonwealth Government level three of these — the Commonwealth Experimental Building Station and the Building Research Liaison Service of the Department of Works, and the C.S.I.R.O. Division of Building Research — are engaged solely on building research or the dissemination of its results. The Defence Standards Laboratories of the Department of Supply undertake research on paints and the Industrial Services Division of the Department of Labour and National Service studies industrial lighting and other aspects of buildings.

In C.S.I.R.O. the Division of Forest Products studies problems in the use of timber for buildings (*see* Chapter 21); the Cement and Refractories Section undertakes research on concrete and cement (*see* Chapter 32); the Soil Mechanics Section studies foundations and soil problems relating to building construction (*see* Chapter 22).

The work of the Division of Building Research continued on the same general lines as in previous years. The emphasis of the research on architectural acoustics has been modified to embrace study of noise in general, with particular reference to problems arising in modern lightweight-type buildings. With the establishment of two works for the manufacture of bloated clay and shale aggregate – one in Sydney and one in Melbourne, investigation into manufacture of lightweight aggregate has largely ceased, and increased attention has been given to use of lightweight concrete in structures.

With the cessation of ceramics research by the Chemical Research Laboratories, the three officers of those Laboratories stationed at the Ceramic Research

Laboratory in the South Australian Institute of Technology were transferred to the Division of Building Research, but seconded to the Australian Mineral Development Laboratories.

With the completion of the first three years of the project sponsored by the Associated Fibrous Plaster Manufactures of Australia (A.F.P.M.A.), occasion was taken to reorganize research on gypsum plaster and plaster products to enable the plaster millers to take a more active part. It was agreed that the £2500 p.a. contribution by the A.F.P.M.A. should be reduced to £2000 p.a. for the next two years, but that the plaster millers should contribute an additional £2000 p.a. for two years.

The Cement and Concrete Association of Australia continued its contribution of £1000 p.a., and numerous other special donations were received.

2. Architectural Acoustics

For some years the Division has been engaged in extensive studies of acoustic properties of auditoria, including acoustical measurements in halls, examination of subjective reactions of listeners, and determination of the effect of artificial echoes added to sounds. This work showed that the requirements for the acoustics of a hall could not be very complex. Large changes in acoustical conditions were needed to cause critical comment from subjects who quickly noted other minor deficiencies of the hall. It was therefore concluded that a hall will be acceptable acoustically if it has a low noise level and no entry of interfering sounds from outside, if it has the correct reverberation time, if there is ample intensity of direct sound and early echoes but no outstanding late echoes or bad focusing effects, if there is adequate provision for the comfort of performers and audience, and if the hall is of such an age that listeners have had sufficient time to become conditioned to it. There has been little adverse criticism of this conception, and in no instance has attention been drawn to any hall that, whilst satisfying the foregoing requirements, is considered to be unsatisfactory acoustically.

Progress has been made on a pulse method for measuring noise transmission of walls. A short sound pulse is provided at regular intervals by a loudspeaker in one room and the response of a microphone in an adjoining room is measured after an elapse of time equal to that taken for the sound to travel directly from speaker to microphone. Transmission by other paths takes longer and so is separated by this technique. Hence studies at various angles of incidence are possible.

Studies at the Division have led to greatly simplified techniques for designing low-frequency acoustical duct filters, and recently these studies have been applied to the design of acoustic absorbent materials. Porous materials, and membranes with and without lightweight backing material, are receiving most attention, and it seems probable that effective new absorbents can be produced at markedly lower cost.

3. Bituminous Materials

Work on bituminous materials has been concentrated mainly on their behaviour under Australian conditions as membranes for flat or low-slope roofs, and ways in which the performance of these membranes might be improved. Following a survey of flat-roof construction throughout Australia several years ago, work on bituminous membranes has continued both in the laboratory and in field trials in which performance has been observed over long periods. Knowledge gleaned from these investigations has been summarized in a publication, now in press, giving basic data to help the designer of built-up bituminous roof membranes.

Further work on bituminous emulsion maintenance treatments for weathered bituminous felts has been undertaken to determine the performance of various types of aluminium paint over the emulsion treatments, after various time intervals between application of emulsion and application of paint. In many cases cracking of paint occurs when applied soon after the emulsion treatment, but this can be largely avoided by allowing the bituminous surface to weather sufficiently.

Laboratory evaluation continued of a number of roofing bitumens and pitches. Other laboratory tests have been concerned with the correct grade of bitumen to use in constructing built-up roofs over decks of various slopes. The slump of various bitumens subjected to controlled temperature-time cycles (based on recorded surface temperatures of actual roofs) has been measured for various slopes. The effect of aging before testing is being investigated.

Various coverings, such as paint, aluminium foil, mineral aggregate, tiles, and concrete, are being examined to determine their suitability for protecting bituminous membranes from the direct rays of the sun. Bituminous-based aluminium paint appears most suitable, having adequate durability and sufficiently low film strength not to crack on shrinking. Aluminium foil is satisfactory as a reflective surface treatment provided precautions are taken to avoid buckling, rupture, or excessive permanent extension along the strip, and provided stronger felts such as organic fibre felts are used beneath them.

To determine whether fungal growth on felts is an important factor in the deterioration of bituminous membranes, samples of deteriorated bituminous organic fibre felts have been studied from roofs in the Melbourne area. This work has shown that the conditions in this area are not conducive to the growth of fungi.

4. Clays and Clay Products

Study continued of the clays of Melbourne and adjacent areas, and most of the data for roofing tile clays have been collected and await collation. Much mineralogical work has been completed on brickmaking clays from the same areas. Mineralogical work has been begun on clays from Adelaide, Hobart, and elsewhere in Tasmania. A paper summarizing general aspects of the correlations of clay mineralogy and ceramic properties in structural clay products has been delivered to the Clay Minerals Group of the Mineralogical Society, London.

Expansion of clay products on exposure to moisture is important in the building industry since it may lead to cracking which, although not always structurally harmful, is at least unsightly. The significance of the phenomenon was discovered by the Division several years ago, and since then a comprehensive study has been made of the cause of the expansion, its prevalance throughout Australia, and ways of overcoming it. The impact of the Division's findings is now becoming increasingly felt in the building industry, and architects and builders are seeking information on the most suitable distribution of expansion joints and other design details to avoid later damage to structures.

A detailed investigation is being undertaken on the relation between quantity of water absorbed by bricks, binding of water by natural exposure, and rate and magnitude of expansion with varying degrees of firing. Particular attention is being paid to the effect of size, since small specimens do not behave in the same way as full-scale products. Studies continued on the constituents responsible for expansion, its mechanism, and possible ways of reducing it by adding materials to the unfired clay.

Studies of deterioration of clay roofing tiles along the sea-coasts of Australia have shown that the most important process in deterioration is the action of salt. This salt is derived either from sea spray near the coast, or dissolved from the body of the tile by the action of rain and concentrated in overlapped or underneath parts of the tile. Tests have been made on a modification of the Marseilles-type roofing tile to reduce deterioration by salt action. The new design of tile significantly reduced deterioration and efflorescence, and sarking the roof slightly reduced deterioration and greatly reduced efflorescence. Silicone treatment of tiles, and high firing temperature (1100°C) were the most effective factors in eliminating both deterioration and efflorescence.

5. Concrete

There has been a change in the character of the Division's work in this field. For the last 10 years two major avenues of research have been followed, one relating to cracking of concrete, and the other to development of lightweight concrete. Most of the specific projects relating to cracking of concrete have now been completed, and this work has been carried far enough for the present. Future activity will be related largely with analysing causes of cracking in actual structures and suggesting remedial treatments. Attention is now being focused on study of lightweight concrete.

Work on this material is now proceeding along two distinct lines. Firstly, mix design data are being obtained for the expanded shale aggregate now available in Melbourne. This project is concerned mainly with the choice of suitable fine natural sands to be used with the coarser lightweight material to provide different levels of workability and strength.

The other project concerns the performance of a reduced-scale, lightweight, concrete, flat-plate structure, which may be regarded as a one-third scale model of one storey of a flat-plate building. It has a $3\frac{1}{2}$ in. thick concrete slab 48 ft by

27 ft spanning three bays in each direction with cantilevers at the ends in the longer direction. Deformation of the structure under dead loads and ambient temperature changes is being recorded.

There is a lack of information on the performance of lightweight aggregate concrete structures and structural members. Because of the reduced modulus of elasticity and the possibility of high creep it is most desirable that information on the deflexion and stiffness of such structures should be obtained.

6. Glass and Glazing

Failures have been investigated of double glazed units in several large office buildings in and around Melbourne. In one building alone, about 70% of the units had allowed water to condense within them and about 40% had cracked. Where water had entered the unit a white deposit, which in some cases completely obscured vision, formed on the glass. Entry of water was due to breakdown of the seal, and at the high temperatures attained by the units the rate of reaction of the water with the glass was accelerated. This resulted in the appearance of white reaction products within a few months. The cause of cracking was a combination of influences rather than a single cause. The most important of these were internal pressures developed in the units; concentration of the load of the units near corners; skewing of the units and jamming in frames through thermal expansion; and tensile stresses at the edge of panes.

For use in the design of glass walls, a tabulation is being assembled of solar radiation data at various hours of the day and at different times of the year for both horizontal and vertical surfaces of various orientations and latitudes.

Examination is continuing of a number of glazing compounds after various periods of natural and accelerated weathering. During the period under review several shear and tensile tests were completed. Relaxation tests were carried out on selected polysulphide ("Thiokol") materials, and the "setting up" process of these materials was studied more closely. Shrinkage of oil-based materials after various periods of exposure is also being followed.

7. Gypsum Plaster

To improve methods of production of gypsum plaster a study is being made of processes involved in its production and setting. Investigations are also being made of fundamental physical chemistry of gypsum plaster and various aspects of its utilization. These include the mechanical properties of plaster for use in load-bearing walls, and the manufacture and decoration of fibrous plaster sheets.

In work on the kinetics of plaster setting a study of variation in setting rate for a number of commercial gypsum plasters has been made. Variations in time of initial set, which from a practical point of view is probably the most important characteristic of plaster, appear to be due to different degrees of seeding with nuclei for the growth of gypsum. Rate of setting after the initial set is also important and different branches of the plaster industry require different rates of setting. Once again the degree of seeding appears the most important factor determining rate of setting, though other factors also make themselves felt.

Study of the mechanism of retardation has been completed and work has begun on the mechanism of gypsum calcination.

The properties of plaster are affected by the physical condition (habit, lattice perfection, etc.) of the gypsum from which it is made, and work is being undertaken on the inner texture of gypsum crystals and the connexion between texture and the properties of the calcined product.

The cause of "water mark staining" on fibrous plaster has not yet been identified. Outbreaks tend to occur in February and March, and there is reason to believe that staining occurs in jobs that were flush jointed during hot weather. This would fit in with observations on the effect of temperature on the microstructure of plaster. Observations in the field seem to eliminate the possibility that stains are derived from noggings or battens.

8. Paint on Plaster

Various types of sealer are being examined to determine their effectiveness in sealing off lead-containing paints which can give rise to sulphide staining by reacting with traces of hydrogen sulphide in the atmosphere.

In cooperation with the Defence Standards Laboratories a study is being made of the durability of fungicides such as phenylmercury compounds in paint films. Suitable analytical procedures have been developed. The commonly used phenylmercury compounds have been found to decompose on exposure to light, and to lose their effectiveness as fungicides by reacting with certain paint pigments.

Identification of salts that cause efflorescence has been continued. It has been found that efflorescence is usually caused by sodium sulphate. Sodium chloride, which is often present, does not show up as efflorescence, but can lead to an adhesion failure of paint films.

9. Stone

Technical advice was made available to all those concerned with the use of stone in building. Visits to sites where stonework is being done has made possible further field observations of the weathering characteristics of stonework in Victoria.

Inquiries have been received regarding white limestone from South Australia and similar stones from the Western District of Victoria. These stones are very soft when freshly quarried, and therefore liable to damage during handling, but on exposure develop a durable skin.

Secondhand slates from the roofs of demolished buildings are finding a ready market especially if they have been cleaned. Some of the chemicals used for cleaning may, however, attack the slate itself, and this action may continue in areas kept wet. Some accelerated weathering after silicone surface treatments have been used has also been noticed.

10. Thermal Investigations

Exprimental work is almost complete in the sponsored research on briquette-fired water and space heaters for the State Electricity Commission of Victoria. Studies have been made of: two units for heating hot water; three units capable of exchanging heat from water to air; two units which heat both air and water; and two units which heat air. Efficiencies of heating air and water based on the net calorific value of the fuel were commonly of the order of 50–60% — this seems likely to be the best attainable with standard designs.

Temperature distribution has been studied throughout a room when heated by a convection stove or by forced warm air. Even with auxiliary fans and ductwork, the former method gives large temperature gradients. Forced warm air circulated at the rate of at least 300 cu. ft. per min seems capable of providing heating without troublesome air temperature gradients.

Mathematical studies of temperature conditions in a typical heavyweight office building showed that, if the external temperature was suddenly to rise 1°F from a steady state and remain thus, the internal temperature would take about 5 days to rise 0.9°F. This is obviously a theoretical case, but it suggests that the usual estimate of 2 days for a building of this nature to respond to the effect of a "cold snap" is in error. Design temperatures for both hot and cold peaks need further careful consideration. An approximate method for studying the response of a building to a sudden change in internal heating rate was published in 1956. This method has now been further developed so that the degree of approximation is far smaller.

Studies were made several years ago relating to "low-temperature" radiation received by building surfaces. These studies have now been extended, and it has been shown that even at midsummer, about one-quarter of the total radiation received by a roof comes from low temperature sources.

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Wool Research Laboratories

The Divisions comprising the Wool Research Laboratories are:

> The Division of Protein Chemistry, Parkville, Vic., responsible for research on the structure and chemistry of wool and industrial processes emerging from this work.
>
> The Division of Textile Physics, Ryde, N.S.W., investigating the physics of wool fibres and assemblies, and engineering aspects of wool processing.
>
> The Division of Textile Industry, Geelong, Vic., responsible for technological investigations.

A Wool Textile Research Committee comprising the Chiefs of the three Divisions is responsible for overall policy and coordination of research in the Wool Research Laboratories. This Committee meets frequently to review research programs, to ensure frequent contact and good communication between research staff working on problems of mutual interest, and to see that the resources of the Divisions are used to best advantage.

Wool has continued to dominate the Australian economy, and contributed 40% of the nation's export income in the 1958–59 financial year. C.S.I.R.O. is paying special attention to problems of the wool textile industry to ensure that public demand is maintained for fabrics manufactured from wool, and to preserve the position of wool among the world's textile fibres.

The work of the Wool Research Laboratories is directed to: increase in understanding of the complex chemical and physical structure of the wool fibre and its relationship to its chemical and physical properties; improvement of wool as a textile fibre; improvement in wool processing and utilization of by-products; and improvement of machinery used in wool textile manufacture.

The work of the Wool Research Laboratories is complementary to research in sheep husbandry undertaken by the Animal Research Laboratories (*see* Chapters 6, 7, 8, and 9), and the Division of Biochemistry and General Nutrition (*see* Chapter 10), which is aimed to increase the quality and production of wool at the pastoral stage.

The Division of Chemical Physics studies the structure of proteins in relation to wool (*see* Chapter 29, Section 2); the Organic Chemistry Section studies the constituents of wool wax (*see* Chapter 34, Section 2); the Division of Entomology studies the digestion of wool by insects (*see* Chapter 11, Section 2).

During the year under review plans have been prepared for the construction of new laboratory buildings at the Division of Textile Industry and the Division of Protein Chemistry to provide laboratory space for an expanded research program. Construction on these buildings will commence in the next financial year.

In May 1960 the Second Quinquennial International Wool Textile Research Conference was held at Harrogate, England, and Australia was represented by a strong delegation, including the Chiefs and 15 officers of the Wool Research Laboratories. This Conference has made it clear that Australia, as the largest producer of apparel wool, must carry the major responsibility for wool textile research, and that no significant increases can be anticipated in overseas wool textile research. Provision of adequate research must, however, be backed by technical promotion of its fruits. During the year under review significant moves in this direction have been made by the Australian Wool Bureau, which has now engaged a number of scientists to carry out technical development functions. Two of these officers have been transferred from the Division of Textile Industry.

To familiarize other scientists with the research of the Wool Research Laboratories, a booklet, "Wool Research Laboratories of C.S.I.R.O. 1960", has been published and sent to scientific research groups throughout the world which may be directly or indirectly interested in the research program.

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Division of Protein Chemistry

1. General

The Division of Protein Chemistry at Parkville, Vic., is one of the three Divisions of the Wool Research Laboratories (*see* Chapter 24). This Division studies a wide range of fundamental problems on the structure and chemistry of wool, and applied problems on industrial processes emerging from this research.

The ultimate object of the Division's fundamental research on proteins is an understanding of the relationship of structure of the wool fibre at molecular level to overall function and properties. Such knowledge should lead to the best means of using wool, and also to possibilities of modifying the fibre to achieve new properties demanded by consumers.

The applied research program is concerned with development into practical technological processes of results obtained from the fundamental research. In addition there is also need to investigate urgent major problems of the industry.

Eighty-five delegates including several overseas visitors attended the first Parkville Symposium on Proteins held at the Division of Protein Chemistry during September 1959. The title given this first meeting was "The Structure and Chemistry of Proteins".

In December 1959 Professor Harold Scheraga of the Department of Chemistry at Cornell University, Ithaca, U.S.A., visited the Division of Protein Chemistry as Guest Lecturer, giving a series of lectures and leading discussions in the first Summer School on Protein Structure to be held at the Division. Research workers on proteins from all Australian research institutes and university departments interested in protein structure attended the 6 day school.

The willing cooperation of the wool producing and selling industry, and the woollen and worsted manufacturers, in the Division's research program is gratefully acknowledged, as is the assistance of chemical and other companies which have cooperated in the Division's investigations. In addition the cooperation of the University of Melbourne's Departments of Bacteriology and Biochemistry and the generous assistance of the Royal Melbourne Hospital, St. Vincent's Hospital, Melbourne, and the Royal Melbourne Hospital Central Linen Service have been features of the investigational program. Excellent relations are being maintained with the Textile Institute of Australia, the Textile Society of Victoria, and the Society of Dyers and Colourists which hold their regular meetings at the Division.

2. Wool Root Biochemistry

Recent investigations confirmed and extended many observations made earlier on amino acids and enzyme systems present in the wool root. Examination of soluble proteins extractable from the bulb region has shown that these can be divided into "high-sulphur" and "low-sulphur" proteins. Similarity in behaviour of these proteins to soluble proteins prepared directly from wool provide useful reassurance that the complexity of the latter does not result from severe conditions necessary for their extraction, but is an inherent factor of wool structure. Medullary cells are largely made up of protein similar in composition to that of the inner root sheath, even to the fact that both contain large amounts of the very unusual amino acid citrulline.

3. Direct Examinations of the Fibre

As many techniques as possible are used to obtain knowledge of the structure of the wool fibre, so that each might shed light on different aspects of the problem and thereby lead to a correct overall picture. The model of wool referred to in the last Annual Report (which envisages the cortex as made up of long crystalline microfibrils about 80 Å in diameter embedded in an amorphous sulphur-rich protein) represents an important synthesis of this kind. Much of the effort of the laboratories over the last year has centred around this idea. Electron microscopy has been used to study the precise packing arrangements of the microfibrils. Four main types of packing of the microfibril have been observed — planar layers; near hexagonal; whorls; and random. The nature of the packing is not of course constant over any large area, and moreover the preferred type of packing changes between the ortho- and paracortex. Thus the orthocortex is usually characterized by large areas where the whorl type of packing predominates. Paracortex, on the other hand, often shows near hexagonal and more random types of packing. Packing arrangements also vary from one particular type of keratin to another; for instance, the best examples of layer packing have so far been observed in porcupine quill tip.

The recent purchase of an optical diffractometer has enabled the effect of these varying packing arrangements on the X-ray diffraction pattern of wool fibres to be studied. In this apparatus the X-ray diffraction pattern is simulated by using visible light. Because of the much longer wavelength of visible light compared to X-rays the objects giving rise to the diffraction pattern can be much larger and yet give a similar pattern. Thus the pattern produced by X-ray diffraction from the atoms of a crystal can be simulated in the optical diffraction apparatus by a mask with holes punched to represent the arrangement of atoms. The outstanding virtue of the apparatus is that it allows ideas on structure problems to be rapidly evaluated; the only alternative approach is weeks of laborious calculation. By this approach it has been shown that the low-angle X-ray diffraction pattern of wool is largely accounted for by the packing of the microfibril matrix complex without making any specific assumptions on the detailed atomic structure of either microfibril or matrix. The detailed structure affects only the high angle X-ray pattern, and although the general interpretation of this based on α-helices is understood, a more complete interpretation must await further work. A very similar approach has also been made to the problem of the structure of feather keratin. This is a β-structure as opposed to the α-structure of wool, but here again the keratin seems to be composed of a two-phase system. Many details of the low-angle photograph can be explained on the basis of this two phase character and are independent of the β-configuration. A much more critical test of these ideas is possible in the case of feather keratin because it is more highly crystalline than any α-keratin. The success achieved with feather keratin confirms the validity of this approach as applied to wool.

Studies on the supercontraction of wool fibres were extended to include chemically modified fibres. The results interpreted in the light of these general ideas have led to the postulation of a more detailed model for wool structure. The model requires stringent testing before its merit can be evaluated, but it has successfully predicted a result which would otherwise have been regarded as improbable.

4. Proteins Extracted from Wool

The idea of the microfibril-matrix complex as the basis of wool structure, coupled with the recent development of relatively straightforward techniques for the separation of different proteins, has given a great impetus to the examination of soluble proteins extracted from wool by a variety of solubilization techniques. In addition to continued work on established procedures involving reduction of disulphide bonds by thioglycollic acid solution at high pH values, these newer separation techniques have permitted rapid evaluation of other procedures such as oxidation, alternative reduction methods, or the new technique developed in the Division involving simultaneous reaction with sulphite and an oxidizing agent. Results in general show a very satisfactory degree of concordance, but have revealed drawbacks to each method. The ideal solution to the problem of solubilizing the wool proteins has still to be discovered. Wool may be made up of a fairly large number of closely related proteins so that the complete separation and characterization of these will be a lengthy process unless vastly improved techniques of protein fractionation are developed. One of the most interesting properties of the "low-sulphur" proteins is their tendency to aggregate strongly in solution. This is obviously important in fibre biosynthesis but makes the interpretation of physico-chemical data very difficult. For these soluble wool proteins no obvious relation exists between the configuration, as measured by optical rotation, and the state of aggregation in a particular solvent.

5. Analytical Techniques

The methods of cystine and cysteine analysis on intact proteins developed in the Division have been used to show that results obtained from protein hydrolysates may give a very misleading picture of the state of the intact protein. It is possible for oxidized wools containing no cystine to give hydrolysates containing cystine, which has arisen by dismutation reactions occurring between intermediate oxidation products of cystine during hydrolysis.

An improved version of the pH-stat and auto-titrator has been developed which is superior to currently available commercial instruments and is finding important applications in a number of problems.

6. Chemical Investigations on the Whole Fibre

The configurational instability of wool protein has been re-emphasized by further work on the extractability of wool following prior mild alkali treatments. This provides strong evidence against chemical theories advanced to explain results, and suggests that the decreased solubility resulting from alkali treatments is a consequence of configurational changes in the proteins. Radioactive tracer studies have demonstrated that undesired side reactions occur during the reduction of wool by thioglycollate solutions. In oxidized wool it has been shown that a previously postulated reaction leading to the formation of cyclic sulphonamides does not in fact occur. A satisfactory explanation has also been found for the evidence leading to this erroneous conclusion. In a specific search for *N*-terminal cystine and cysteine residues in wool it was discovered that these were in fact the second most abundant *N*-terminal residues of wool. They had been previously overlooked because of the instability of their dinitrophenyl derivatives to acid hydrolysis, and could be detected only by oxidation to dinitrophenylcysteic residues prior to hydrolysis. The differential absorption spectrum of pale-coloured fine-wool fabrics in the visible and ultraviolet regions can be measured by immersing a strip of the fabric in a liquid having a refractive index close to that of wool. Using this technique it is possible to follow quantitatively the yellowing of wool by ultraviolet light or weakly alkaline solutions at high temperatures. The sulphur-containing amino acid cystine appears chiefly responsible for the discoloration. The visible discoloration is in fact merely the toe of a very intense absorption band in the ultraviolet with a peak at 3200 Å. No practical procedure for protecting wool from this discoloration has yet emerged.

7. Studies Using Model Compounds

Insulin is being used increasingly as a model compound for protein studies. It is readily available and its complete chemical structure is known. Its high sulphur content makes it particularly suitable as a model for wool proteins, and it has been used in this way to explore techniques of chromatography of proteins on DEAE cellulose. It has also been used to investigate a possible chemical technique for the specific fission of peptide bonds involving tyrosine. The specificity of the reaction was confirmed, but unfortunately it was far from quantitative. Much simpler model compounds have been used in other studies. The reactions of cysteine and cysteine peptides with chloroacetamide have been studied in some detail to obtain information on factors affecting the reactivity of sulphydryl groups. Simpler organic thiolsulphates have also been studied and new reactions of these compounds discovered. Disulphide bonds in wool can readily be converted to thiolsulphates by the use of sulphite and an oxidizing agent, so that possible ways of exploiting this functional group are worth consideration.

8. Hospital Blankets

The work on sterilization of hospital blankets, which demonstrated the possibility of repeated washing of blankets without shrinkage troubles, has led to interest by the general public in washable blankets, and these are now in commercial production. The success of the work has also led to further work on cross-infection problems in hospitals. Textile fibres may not be implicated to any extent in cross-infection, and other mechanisms will have to be investigated. It has been established beyond any reasonable doubt that the major fibres present in hospital dust are cotton and cellulose and not wool. On the average only 3% of fibres in hospital dust are wool.

9. Carbonization

A survey has been completed of a very large number of commercially available detergents with reference to their possible use in carbonizing.

10. Biological Degradation of Cellulose

Effort is being concentrated on enzyme (i.e. protein) studies. This is of direct concern in the application of enzymes for conferring on wool properties such as unshrinkability. The whole problem of the action of enzymes on insoluble fibrous substrates is a virtually untouched field.

11. Jute Contamination

The Australian Wool Bureau, the National Council of Wool Selling Brokers of Australia, the Australian Council of Woolbuyers, and C.S.I.R.O. authorized the printing of a leaflet alerting woolgrowers to the problem of jute contamination and asking them to remove all surplus yarn and twine from packs before baling. With the generous cooperation of members of the National Council of Wool Selling Brokers of Australia this notice was distributed to all woolgrowers throughout Australia. The Indian Jute Mills Association Research Institute is cooperating in experiments on alternative methods of shipping new packs to reduce subsequent contamination from tie strings.

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Division of Textile Physics

1. General

The Division of Textile Physics at Ryde, N.S.W., is one of the three Divisions of the Wool Research Laboratories (*see* Chapter 24). This Division undertakes fundamental study of the physics of wool fibres and assemblies, and investigates engineering aspects of wool processing. The behaviour of textile fibres during manufacturing operations and their performance in cloth and garments depend largely on their physical properties. Much of the research of the Division is carried out on single fibres, and these investigations are providing new knowledge on the internal structure of wool, as well as data of value in textile processing.

There have been no major changes during the year in the research program of the Division of Textile Physics. Investigations of water sorption and molecular configuration by means of elastic, electrical, and kinetic regain have continued as a major interest of the Division. Other fields of study have been: dimensional properties of cloths; spinning; dyeing; drying; and the properties and measurement of raw wool.

2. Raw Wool

(1) *Coring Tools.*—A set of the tools recently developed by C.S.I.R.O. for cutting sample cores from wool in baled form has been presented to the Australian Wool Testing Authority. With the new design the same staff is sampling twice as many bales as with the old rotary coring equipment. The new design has been patented in Australia, and an arrangement made for the Australian Wool Testing Authority to act as the Organization's distributing agents for these tools.

(2) *Tender Wool.*—Trade practice in appraising tenderness was investigated. It was found that there was 50 : 50 chance that wool would be penalized for tenderness, if its strength was less than one-third of that of a wool grown on a good, uniform diet. Strength measurements of wool grown on a drought-feeding ration showed that reduction in strength was due simply to reduction in diameter of the fibres, not to a deterioration of their inherent strength.

3. Wool Textile Processes

(i) *Dyeing*

The solvent dyeing process, in which organic solvents are used as assistants in the dye-bath, has been investigated in cooperation with an officer of the Wool Industries Research Association of England. Increase in rate of uptake has been shown to be due to faster movement of dye within the fibre, and not, as had been suggested by others, to formation of a dye-rich surface layer.

(ii) *Spinning*

A novel method of spinning direct from top has been investigated which is designed to reduce the many intermediate drawing processes at present in use. The basis of the new method is that fibres are pulled from the top by twist, the operation being servo-controlled by the withdrawal tension. The method has been developed into a working model, but not to the stage of producing yarn of a commercially acceptable standard.

(iii) *Dimensional Stability of Cloth*

(1) *Felting Mechanism*.—A new felting mechanism has been identified which is important in single woollen yarns. In making yarn, fibres are twisted into the configuration of helical coils, which imposes on the fibres a strain of curvature. Fibres tend continually to reduce this strain by increasing the radius of the coils. This causes a reduction in length of the yarns, and therefore shrinkage of the cloth.

For worsteds no felting takes place until the force of agitation exceeds a certain level, and a period of agitation (called the inductions period) is also necessary before felting commences.

(2) *Relaxation Tester*.—An instrument has been patented to measure the relaxation shrinkage of fabric samples quickly to within ¼%. It needs only a minimum of manual operation, and completes the measurement in about 5 min. By other methods the measurement takes several hours.

A detailed study is being made of the reason for hydral expansion, which is the reversible change of dimensions which takes place in wool fabrics with change in moisture content.

(3) *Flexural Rigidity*.—Mathematical studies of cloth mechanics have revealed an easy way of measuring the flexural rigidity of cloth. If a strip of cloth is laid on a horizontal surface, and one end folded back to the other, without creasing the fold, the height of the fold is equal to 0.90 times the ratio of the cube root of the modulus of rigidity per unit width to the weight per unit area of the material.

(iv) *Regain*

Accurate data have been obtained of the dependence of dry weight on previous conditioning history, and of rates of regain change under various conditions. This knowledge has led to the development of two drying instruments. One is a rapid automatic regain tester of rugged design, suitable for industrial use, which will enable regain determinations to be made within a few minutes without any calculations. This tester should lead to a closer control of regain in the wool manufacturing industry. The other instrument is a precision certificate oven for rapid determination of regain. This oven has enabled the low regain portion of the wool-water sorption isotherm to be determined at 105°C, together with its influence on drying for certificate purposes.

Single fibre studies have also been extended to the drying of masses of wool (with special reference to the practice and performance of industrial dryers). One possibility examined is the use of unheated air for drying, a process which may have advantages both from the point of view of economics and of quality. An analysis of meteorological data for a 5-year period for a number of Australian locations has yielded the following minimum and maximum operating costs: Bourke (N.S.W.) 0.16*d.*/lb of water removed; Hobart 0.33*d.*/lb. These figures are to be compared to 0.43*d.*/lb for a conventional hot air dryer. Studies are now under way to bring the principle of drying with unheated air into practical realization.

4. Physics of Wool and Fibre Assemblies

Mechanical Properties of Single Fibres

(1) *Transition Temperatures*.—The existence of a transition temperature of 60–70°C for wool when under tension, reported a year ago, has been confirmed by measurement of decrease in stress in a fibre held at a fixed extension. Above the transition temperature the decrease in 1 hr was approximately 73%; below the transition temperature the decrease was approximately 33%. An irreversible change appeared to take place in stretching at temperatures above the transition temperature — the fibre being permanently extended in length and weakened.

A transition temperature has also been demonstrated in collagen, the basic material of tendons, skin, and connective tissue. This is of medical significance, especially in regard to rheumatic complaints, for the transition temperature of 37–40°C is only a little above the normal temperature of the human body, and therefore indicates possible damage through exertion when suffering from a fever.

(2) *Moduli of Longitudinal and Lateral Compression*.—By using an interference technique Young's modulus of keratin in compression along its axis was measured on small blocks of horsehair of length equal to their diameter. The modulus in compression was found to be about twice that in extension. This is in accord with other evidence that the modulus in extension is reduced by breakage of some bonds (in the matrix) which would be expected to hold in compression. In transverse compression the Young's modulus could not be measured, but the ratio of the modulus when dry to the modulus when wet could be measured, and was found to be about 20 : 1. This is to be compared with a ratio of about 3.7 : 1 for the dry and wet longitudinal moduli. The greater decrease in the transverse modulus is in accord with other evidence that chains (microfibrils) of molecules, which are almost unaffected by water absorption, run longitudinally in the fibre, and are surrounded by a water absorbing matrix.

5. Electrical Properties

Further accurate measurements of the electrical conductance of fibres have contributed to the study of fibre structure. When a fibre at a constant regain of about 23% at 35°C was stretched, its conductance did not decrease till the end of the Hookean region (2% strain), and the decrease was then linear till 50% strain. This behaviour can be accounted for exactly by concepts of structure currently being developed, viz. that conduction is due to water in the matrix, not the microfibrils, and that in the Hookean region no bonds are broken in the microfibrils, but thereafter extension of the fibre entails breakage of an increasing number of hydrogen bonds in the α-helix chain of the microfibrils. The proportion of bonds broken at any extension can be calculated from the known relation between bond lengths in the broken and unbroken states. The decrease in conductance is then exactly accounted for by assuming that a water molecule leaves the matrix and enters the microfibril each time a bond in the microfibril is broken.

Problems in measuring the extremely small conductance of almost dry fibres have now been overcome. This resistance is much higher than previously reported, and no increase in conductance occurs as a result of the first 2% of water absorbed. This confirms other evidence that the first 2% of water is chemically bound.

6. Ultraviolet Penetration

Ultraviolet light affects the interior of fibres much more than would be predicted from data on absorption rates. Evidence suggests that this effect is due to exciton action.

7. Fibre Structure

X-ray diffraction patterns of iodinated wool suggest that the tyrosine residues are near the outside of the microfibrils.

Perfluoro-octanoic acid is capable of rapidly entering the crystalline structure of keratin and collagen, producing a state like supercontraction.

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Division of Textile Industry

1. General

The Division of Textile Industry at Geelong, Vic., is one of the three Divisions of the Wool Research Laboratories (*see* Chapter 24). This Division is concerned with improvement in wool properties, products, and textile processing operations. A large proportion of the Australian wool clip is used for worsted materials, and for this reason the Division has given special attention to processes of the worsted system. Geelong is an important wool processing centre, and location of the Division there allows close contact with the industry.

There has been wide application of processes and equipment which have resulted from the Division's research. The SI-RO-SET permanent creasing process is now well established in several countries, particularly Australia, New Zealand, Belgium, Holland, and Japan. The "SIRONIZED" treatment, conferring washable non-iron effects in wool fabrics, has reached commercial application in Australia, where treated shirts have appeared on the market. Concurrently with this work, a shrinkproofing process has been developed for wool based on treatment with permanganate and salt, and is now being applied particularly for blankets and knitwear.

The Noble comb control units are operating successfully in Australian mills and four units have now been installed in Bradford. The solvent degreasing process is in commercial operation in one Australian mill and the plant was officially opened by the Premier of South Australia on May 10, 1960.

Textile finishing equipment installed at the Division during the year has facilitated development of processes such as shrinkproofing and wash non-iron treatments.

There has been close collaboration with the Wool Bureau Technical Liaison Section and local mills in treating fabric for wash non-iron effects and in demonstrating such processes to industry.

2. Branding Fluid

SI-RO-MARK branding fluid continues to be widely used. From the point of view of mill processing, the problem appears to be overcome, but there is still need for research to eliminate difficulties occasionally experienced with field performance. Work on ultraviolet screening compounds to reduce actinic degradation is still in progress. Results to date indicate that such materials may not be effective at economic addition rates. A formula for identification crayons, developed in collaboration with the Animal Research Laboratories, is now in commercial production.

3. Solvent Degreasing

The commercial solvent degreasing plant was officially opened during the year. The pilot plant at Geelong has been completely rebuilt to enable tests to be carried out over a wider range of conditions, and a Fleissner dryer installed to cope with the increased production rate. All conveyors were replaced by perforated drums or rolls; squeeze rolls were introduced after each jetting stage; the number of solvent and water jets was considerably reduced; and the operating jet pressures were increased. The new operating conditions have resulted in a considerable reduction in size of the plant (allowing easier enclosure for prevention of solvent loss) and reduced maintenance requirements.

On this equipment, improved solvent recovery has been obtained by using warm water in the water jetting section. Other means of solvent economy are also being studied.

Determination of overall heat transfer coefficients in an experimental dirt dryer has provided reliable data for design of full-scale dirt dryers to recover solvent from the dirt cake.

A total of 150,000 lb of greasy wool was processed through the pilot plant during the year, most of it for industrial trials in Australia and overseas.

Research has continued on the finding previously reported that solvent degreasing gives increased yield of wool compared with alkaline soap scouring. This has been confirmed both in laboratory and further industrial trials. The more open fleeces, or those with lower wax contents (which are more susceptible to ultraviolet degradation of the tip) show the greater differences. In addition, several trials on the woollen system, as distinct from the worsted, have shown that higher yields of wool are obtained after carbonizing.

4. Fleece By-Products

Investigations on refining processes, particularly for solvent lanolin, have been continued in the laboratory, and a large refining plant has been built for works-scale studies. Numerous chemicals have been tested for bleaching efficiency under various conditions. The effects of neutralization procedure and other variables on centrifugal recovery are being investigated, and this work may lead to improved recoveries in the centrifugal separation of lanolin from scour liquors.

Fundamental research on the surface activity of lanolin and lanolin components was carried out by one of the research staff stationed at Leeds University under an International Wool Secretariat scholarship.

5. Wool Textile Processes

(1) *Carding.*—The sliver converter system, which is being developed, has been closely studied, and attachments have been introduced to remove vegetable material. Several promising methods of burr removal are being studied and satisfactory preliminary tests have been carried out on one which could have practical application.

The effect of lubricants on wool during worsted carding has been closely studied. There appears to be an optimum content of lubricant of the order of 0.5% and the viscosity of the product used is of prime importance. Apparatus has been constructed for determining the friction between fibres and card wire, and this is being used to assess the effects of oils of various viscosities. In addition, tests have proceeded on full-scale mill equipment to assess fibre breakage, wastage, and subsequent combing performance of wool in the presence of different lubricants. The high rates of carding with solvent degreased wool have been confirmed. It has also been possible to eliminate a section of the card and produce satisfactory sliver from solvent degreased wool.

(2) *Combing.*—The comb control units have given satisfactory results over the past year in Australian worsted mills. Considerable time was spent in making sure that the initial application of this equipment was successful. This involved much collaboration between research staff and firms concerned with the manufacture and installation of the units. Four units have been installed in Bradford and are undergoing initial trials. An experimental Noble comb is being constructed to permit laboratory measurements on wool subjected to the mechanical actions received in Noble combing. This equipment should lead to a better understanding of the combing process and possible ways of obtaining improved results. The French comb is also being studied and an investigation has commenced on the fundamental processes involved in the action of this important machine.

(3) *Yarn Sizing.*—An investigation of the application of size materials to pure wool yarns has begun. Initially a single-end laboratory sizing machine has been constructed and used to apply various materials to yarn, and to correlate changes in yarn properties with amount of size add-on. A new method has been found for laying protruding surface fibres by transversely rubbing freshly sized yarn prior to drying. A yarn abrasion tester has also been developed to determine the abrasion resistance of sized yarn when rubbed yarn against yarn.

6. Modification of Wool

(1) *Shrinkproofing.*—Studies continued on analysis of scales removed from fibres shrinkproofed by various reagents. With chlorine, potassium permanganate, and sulphuryl chloride, the main chemical change taking place is attack on the cystine in the scales. Other amino acids do not appear to be affected. Alcoholic alkali leaves the cuticle unchanged chemically, the main action being removal of a small amount of surface material. The method is proving useful in finding chemical changes in the scales which do not show up when analysis of the whole

fibre is undertaken. The method of collecting scales has been to remove them mechanically from each fibre, which is a very tedious process. Recently, a new method has been developed which depends upon removal of scales from fibres by means of ultrasonics.

The physical changes are being examined which occur on the scales of fibres as a result of modification by chemical shrinkproofing techniques. Frictional measurements are being carried out, and an effort is being made to correlate these with visual changes in the surface microscopic appearance of the fibres resulting from treatment.

The permanganate-salt treatment for shrinkproofing wool, described last year, has been extensively developed. It has been shown that the residual oil content of fibres can have a marked effect on the results of treatment. Oils added during processing can interfere with results, and it is necessary to subject the wool to a preliminary scouring operation to remove most of this oil. Scouring in non-ionic detergents in the presence of sodium chloride or sodium phosphate is most effective. Trials have been carried out extending the treatment to tops, knitwear, and yarn, in addition to woven fabric on which it was originally developed. Satisfactory results have been obtained in all these forms of treatment. An outstanding property of treated wool is that the handle is unaffected. Also the subsequent softening, usually required with most chemical shrinkproofing reagents, is unnecessary.

(2) *Mothproofing.*—The method of mothproofing using dieldrin has continued to extend to other countries, and assistance has been given to organizations overseas interested in its adoption. In U.S.A. it has been widely taken up, and more than 100 mills now use the process. It is also extensively adopted in Japan and Europe.

(3) *Permanent Pleating.*—The SI-RO-SET process has been extended in Australia in collaboration with the Wool Bureau Technical Liaison Section. There has been an increase in the number of licensed users of the process, particularly in the pleating of women's skirts. In most capital cities, commission treatment plants are now established where trousers can be treated for small tailors or other interested firms. Several Government Departments now specify the treatment in their contracts. Experiments in collaboration with the Australian Wool Bureau Technical Liaison Section have shown that the treatment could be applied satisfactorily to set felts for use in loud speaker cones. This could open up a possible new use for wool.

(4) *Wash and Wear.*—The process for producing washable non-iron effects in wool was released to industry during the year, and treated garments have now appeared on the Australian market. The method consists of first shrinkproofing the fabric, and then flat setting by steaming in the presence of sodium bisulphite, finally drying with little or no tension to minimize subsequent relaxation shrinkage. Extensive laboratory and mill research has been undertaken on this project. A series of fabrics has been constructed using yarns of different twist and ply, and weaving at various densities to ascertain the optimum types of fabric for treatment.

Yarn twist, and ends and picks per inch, are extremely important factors in producing satisfactory materials. Best results are obtained on fabrics with high yarn twist and dense construction. With lightweight fabrics, variations in tensions of the yarn during operations such as winding can produce surface irregularities in the final fabric on washing. Consequently it will be important for fabrics treated by the bisulphite setting procedure to be properly constructed. In addition to fabric structure, garment structure is also important. Experiments are in progress ascertaining the optimum conditions for sewing, as well as the right types of lining materials for use in garments made from treated fabric. Mercurized cotton or nylon thread has been found satisfactory, whilst a stiffened cotton lawn has given excellent results as lining material. In a series of wearer trials, treated shirts were worn and washed up to 200 times without sign of shrinkage or need for ironing. It has also been possible to machine-wash and tumble-dry treated garments, again without shrinkage or need for ironing.

(5) *Pilling*.—Research on pilling has continued. Certain shrinkproofing treatments will markedly reduce the amount of pilling which can occur in knitwear. The permanganate-salt process of shrinkproofing is particularly effective in this way, and garments treated by this method have been practically free from pilling during wearing trials. Moisture content of the wool appears to be a significant factor in pilling, high humidities favouring more pilling than low humidities.

28

Chemical Research Laboratories

1. General

The Chemical Research Laboratories, formerly the Division of Industrial Chemistry, constitute the major concentration of chemical research within C.S.I.R.O., although much chemical work is undertaken in other Divisions and Sections.

The terms of reference of the Laboratories are: to promote technical efficiency in established industries; to stimulate the establishment of new industries; to encourage use of raw materials of Australian origin; to seek substitutes for imported materials; to find uses for by-products not utilized; and to study national problems to which research staff can contribute by virtue of their experience in other fields.

The following are the Divisions and Sections which comprise the Chemical Research Laboratories:

The *Division of Chemical Physics* studying spectroscopy, crystallography, chemical physics of the solid state, and development of new instruments and techniques (*see* Chapter 29).

The *Division of Physical Chemistry* studying such projects as water conservation, bushfire research, carbon chemistry, fluids research, influence of pressure on chemical reactions, photochemistry, and enzyme chemistry (*see* Chapter 30).

The *Division of Mineral Chemistry* studying utilization of minerals and their derived products (*see* Chapter 31).

The *Cement and Refractories Section* studying the basic chemistry of cement and concrete, and the fabrication of special refractories and hard materials (*see* Chapter 32).

The *Chemical Engineering Section* studying chemical engineering techniques in such fields as hydrogenation of brown coal and desalting of saline water (*see* Chapter 33).

The *Organic Chemistry Section* studying biological problems and potential organic raw materials of Australian origin for the chemical industry (*see* Chapter 34).

The *Foundry Sands Section* studying foundry problems with special reference to moulding sands (*see* Section 2 of this Chapter).

Officers of the Laboratories continued to play important parts in the activities of professional and learned societies, and many officers have earned distinction this year.

2. Foundry Sands Investigations

The laboratory of the Foundry Sands Investigations unit is located in the Metallurgy Department of the Royal Melbourne Technical College and is equipped to study foundry problems with special reference to moulding sands. The unit maintains a catalogue of Australian moulding sands. A review of foundry practice in Australia was recently presented to a meeting of British foundrymen in London so that facilities and opportunities for new industries in this country could be described. Preparations are now being made for a more detailed survey of the foundry industry to formulate a research program.

Work continued on bentonites from Marchagee, Western Australia, and on newly discovered clays of this type from New South Wales and Victoria. All these are inferior in some respects to imported bentonites used as binding agents in synthetic foundry sands, but attempts are being made, in collaboration with the Cement and Refractories Section, to modify them for this application.

Investigations continued on expansion defects in castings, refinements being made to the crust-separation test developed earlier. The efficacy of this test has been demonstrated in assessing the usefulness of the various additives traditionally used in synthetic sands, and it has been shown that the test can now be used with confidence to control sand preparation. A further factor in the formation of expansion defects is failure under shear of the bond between crust and wet sand adjacent to it. An apparatus has been devised for measuring the shear strength of sands. This property is associated with the action of the added bentonite, the main purpose of which appears to be to increase this shear strength.

A new method of producing aluminium-clad steel by cold-rolling has been described. A limitation, imposed by the embrittlement that follows the formation of iron-aluminium compounds during annealing between successive rolling stages, has been overcome by the use of an aluminium-silicon alloy or elemental silicon, both of which inhibit formation of this compound.

29

Division of Chemical Physics

1. General

The Division of Chemical Physics is one of the Divisions of the Chemical Research Laboratories (*see* Chapter 28). The Division of Chemical Physics undertakes fundamental research in the fields of spectroscopy, crystallography, and solid state chemistry and physics; the Division also develops new instruments and techniques for basic research and industrial application.

Collaboration with and service to industry, universities, and establishments of C.S.I.R.O. has again represented a substantial part of the Division's activity. Instruments and techniques developed within the Division have been the subject of increased commercial exploitation, both in Australia and abroad. Royalties received on the multiple monochromator and atomic absorption patents now total $83,000.

The Division's work has again been recognized overseas by invitations to its officers to participate in conferences and research programs in other countries. Dr. A. Walsh was an invited speaker at the Pittsburg Spectroscopy Conference in March 1960, and conferred by invitation with spectroscopic instrument manufacturers in U.S.A., the United Kingdom, and Italy. Dr. J. D. Morrison was an invited speaker at the American Chemical Society Meeting on "Non-analytical Applications of Mass Spectrometry" at Atlantic City in September 1959. Dr. C. K. Coogan was invited to participate for a second year in the Visiting Research Scientists' Program by the U.S. National Academy of Sciences.

Officers of the Division played an active part in organization of the International Symposium on "The Chemistry of Natural Products", held in Australia in 1960. The Division also organized the Second Australian Spectroscopy Conference held in Melbourne in 1959.

Professor Bayliss has continued to provide accommodation and supervision at the University of Western Australia for certain aspects of the atomic absorption spectroscopic work. His helpful cooperation is gratefully acknowledged.

The cooperation is greatly appreciated of Dr. J. M. Bennett and Dr. H. C. Freeman of the University of Sydney, and Mr. R. G. Smart of the University of

New South Wales, in carrying out the computing involved in some of the crystallographic studies.

2. Crystallography

Work continued on development of X-ray, electron diffraction, and electron microscopy techniques, and on application of these techniques to problems of special significance. Development of these techniques covers a wide range of activities, including study of fundamental processes of scattering of radiation by solids, design and modification of instruments to broaden the range of experimental methods, and testing of new methods for interpretation of experimental results. Application of these techniques to protein structural studies is an important part of the Section's program.

(i) *Theoretical Studies*

(1) *Electron Diffraction and Electron Microscopy.*—Formulation of the theory of scattering of electrons by crystals on the basis of ideas originating in physical optics, which was developed in the Division, has proved its worth in further applications to problems of practical interest. Relatively simple formulae, based on the first approximation to this theory, can give an adequate description of details of image contrast obtained when a modern high-resolution electron microscope is used to image the periodicity of crystal lattice structure, and defects which occur in such structures. Great interest has recently been shown in imaging dislocations in metal crystals, and previous attempts to interpret the effects produced by such dislocations in images have been limited and cumbersome.

The same first approximation has allowed estimates to be made of the way in which intensities of electron diffraction power patterns may deviate from intensities calculated from simple kinematic theory. It has been shown that, particularly if heavy atoms are present, large deviations may be expected even for very thin crystals, no more than a few unit cells thick. The only other treatment of the problem, which has been the standard treatment for many years, is grossly and qualitatively wrong in most cases. Measurements of intensities of reflections from oriented bismuth oxychloride crystals have fully confirmed these theoretical predictions.

Some work has begun on the basis of this scattering theory to include the effects of the inelastic scattering processes.

(2) *Disorder in Crystals.*—It became apparent, in course of calculating the diffraction from disordered crystals, that the concept of a Patterson function used in diffraction theory could be applied to formulation of thermodynamic equilibrium conditions for disordered alloys or similar systems. This has led to revision of a previous theory of order-disorder phenomena in alloys. The new treatment of this problem has placed the theory on a more satisfactory basis, and also led to new results, including an explanation for formation of the out-of-phase domain superlattices which have recently been shown to be of common occurrence in alloy systems.

(3) *Atomic Scattering Factors.*—The atomic scattering factors for X-rays and electrons which are now generally employed in refined structural calculations are those based on the Hartree-Fock approximations. Calculations based on the more accurate "poly-determinantal" approximations have now revealed inadequacies of the Hartree-Fock scattering factors especially for negative ions. Critical tests are provided by the error-sensitive calculations of detailed electron distributions in simple ionic lattices, and of atomic factors for electron scattering at very low angles.

(ii) *Instrumental Developments*

(1) *Electron Microscope Contrast.*—A major difficulty in electron microscopy is the poor contrast given by specimens composed of light atoms. Two obvious approaches to this problem are development of stains containing heavy atoms and exploration of the electron-optical possibilities of improving contrast. Work on both of these approaches is in progress.

In the course of application of staining methods to plant material, results were obtained which suggested that structures commonly attributed to the chloroplasts of certain plants were incorrect. It has now been established that the ultrastructure of these chloroplasts is practically identical with that found in a range of higher plants studied in this Division in recent years.

A new staining method developed overseas has permitted the resolution of the molecules in a protein crystal which was quite inert to the most drastic treatment with conventional stains. This technique will permit resumption of study of protein crystals abandoned several years ago owing to lack of adequate contrast.

A standard method of obtaining greater contrast is by defocusing which enhances the phase contrast. Unfortunately this method yields images which bear such complex relationships to their objects that they can be interpreted only in certain simple cases. Of many possible electron-optical means of altering the relation between image contrast and object structure, the simplest are various dark-ground methods of illumination. Experiments carried out to date show that with very thin specimens a resolution of about 30 Å is attainable by oblique dark-ground illumination. With central dark-ground illumination the results are rather poorer. Refinement of these and other methods is being pursued.

(2) *Electron Diffraction Instruments.*—The factor limiting resolution in the Division's electron diffraction instruments was found to be, in practice, brightness of the electron source. With existing electron guns higher resolution could be obtained only with excessive exposure times. It has now been found that the intensity of the electron source can be increased about a hundred times by a modification of the gun design, using a smaller grid hole and a more sharply bent filament. Further improvements in resolution are now possible, allowing study of a new range of fine-structure effects.

Electrostatic deflector plates in an electron diffraction camera were first developed in this Division and used for measurement of integrated intensities in single-crystal spot patterns. Further uses for deflector plates have now been developed. By placing deflector plates above the specimen it is possible to provide a motion of the electron beam relative to the specimen to a very much finer and more reproducible degree than that achieved by mechanical movement of the specimen. This is of great importance since the dimensions of crystals and beam cross section normally employed are of the order of a micron. A preliminary search of an area of specimen for a crystal of particular interest may be made by putting alternating voltages of variable amplitude on these same deflector plates.

Another use of deflector plates has been found in a chopper system whereby the electron beam may be pulsed in a controllable manner. This forms part of a device now being developed for accurate measurement of electron beam intensities.

(3) *Analogue Computer.*—The analogue computer, ISAAC, which is designed to assist in preliminary stages of analysis of crystal structures from diffraction data, is now approaching completion, and initial tests to examine its potentialities have begun.

(4) *Counter-current Processes.*—Investigation of counter-current liquid-liquid extraction processes operating under reflux arose as an interesting adjunct to the program of peptide synthesis because of need for high-purity intermediate products. Two processes considered, the "dissociation extraction" process and the simple partition process, have now been given adequate theoretical treatment, and have been tested sufficiently with suitable samples to establish their ranges of usefulness.

(iii) *Specific Applications*

(1) *Structures of Large Molecules.*—Earlier work on X-ray determinations of structures of moderately complex molecules, lanostenol and cryptopleurine, indicated that serious restrictions in such methods were imposed by the limited range of diffraction data and by the deleterious effects of large molecular thermal motions. To obtain additional data with reasonable exposures a high-power X-ray generator was constructed, and thermal effects were overcome by cooling the crystal to $-150°C$ during exposure.

With this experimental set-up, analyses of several natural products have been carried out using full or partial three-dimensional data. Three have been solved completely — himbacine hydrobromide ($C_{22}H_{35}NO_2.HBr.H_2O$), jacobine bromhydrin ($2XC_{18}H_{26}NO_6Br.C_2H_5OH$), and thelepogine methiodide ($C_{20}H_{33}NO.CH_3I$). These compounds were selected because their structures and configurations were largely unknown and for their significance to the natural product chemist in Australia. For similar reasons, an analysis has been initiated on the CCl_4 adduct of sporidesmin, $C_{19}H_{21}O_6N_3S_2Cl$, the agent recently discovered as the cause of facial eczema in sheep.

Such complex molecules permit critical assessment of certain techniques of structure analysis. Earlier tests of summation image-seeking methods in two dimensions have been extended to the three-dimensional case for jacobine bromhydrin, where 55 atoms had to be located to define the structure. This test revealed serious limitations in the process, and indicated the necessity to use a combination of techniques to obtain an unequivocal answer in the minimum number of stages.

The large number of calculations involved in such analyses required the extensive use of available electronic computers. SILLIAC (University of Sydney) and UTECOM (University of New South Wales) have been used, the former for partial and the latter for full three-dimensional calculations. With these, several analyses can be carried on simultaneously and the rate of solution of the problem remains reasonable. With this approach and starting from the empirical formula, a final answer can be achieved in many cases more expeditiously than by the classical technique of the organic chemist.

Final analyses have revealed complete and detailed information on bond lengths and angles in the molecule, thereby defining conformation and relative configuration where the molecule is asymmetric. Definition of the absolute configuration of himbacine hydrobromide was made using the anomalous dispersion of Cu Kα radiation by the bromine atom.

Analyses of natural products by use of "heavy atoms" have shown that the solution and refinement of a crystal structure (particularly if hydrogen atoms are to be located) depends on the accuracy of the scattering curves of the "heavy" atoms. The new scattering curves for Cl^- and F^- have been employed to estimate a more reliable scattering curve for I^-. Evidence of inadequacy in the older value of scattering curve for iodine was noted in analysis of thelepogine methiodide, and the final stages were facilitated by the use of the improved curve.

(2) *Diffraction by Clay Minerals*.—Single-crystal electron-diffraction spot patterns from minute crystallites of montmorillonite show symmetry and relative intensities which do not accord with the structure deduced from X-ray diffraction evidence. Explanation for the observed anomalies has been found in terms of a bending or other distortion of the crystallites. Bending can cause different parts of the complex silicate layers to diffract independently. The same effect has been used to explain anomalies previously observed in X-ray diffraction powder patterns of clay minerals. A number of observations made in course of electron diffraction structure analyses may now be given a satisfactory explanation on this same basis. The range of applicability of electron diffraction methods for structure analysis may thereby be increased.

3. Solid State Physics

Knowledge of solid state physics is of basic importance in many branches of the chemical, electrical, and metallurgical industries. Study continued on selected systems and processes, understanding of which is of fundamental importance in solid state physics.

Some of the Division's work on theoretical chemistry, not necessarily directly related to studies of the solid state, is also carried out in the Solid State Physics Section of the Division.

(1) *Oxidation Kinetics of Molten Zinc*.—Investigation of the oxidation kinetics of molten zinc, completed during the year, confirmed a fundamental model of the manner of growth of the oxide layer at high temperatures.

In picturing the oxidation process it is necessary to describe how zinc and oxygen can react when an intermediate oxide layer forms. For example, in a perfect arrangement of zinc and oxygen atoms it would be extremely difficult to move zinc or oxygen atoms through an oxide layer by a process of "squeezing" them round one another. However, the structure of zinc oxide is imperfect in that it contains an excess number of zinc atoms, and the material is said to be non-stoichiometric containing lattice defects. Presence of these lattice defects provides a way in which zinc or oxygen atoms can diffuse through the bulk of the oxide material.

Investigations confirmed that reaction of zinc and oxygen to form zinc oxide occurs by a process of diffusion associated with defects due to the presence of excess zinc.

This conclusion is important not only for the way in which oxide films are formed on zinc, but also to the problem of zinc oxide as a semi-conducting material. Experimental techniques developed for these zinc measurements are applicable to a variety of problems involving reactions of gases with solids or liquids.

(2) *Phosphorescence.*—Successful development of the phosphorometer from ideas that originated 15 years ago is an example of the application of new ideas and newly developed materials to old problems. A hundred years ago the classical apparatus for studying phosphorescence lifetimes was built to study afterglow. Now developments in the field of solid state chemistry have shown the need for a proper understanding of afterglow on an atomic scale. The present work has developed not only the instrument, but several new conceptions of phosphorescence, and an analytical technique for reducing experimental data to a comprehensible form. Success of the project depended upon making measurements that were almost 10 times more precise than any previous attempt, and until enough high quality data had been analysed and compared it was impossible to tell whether the approach was justified, and whether the new concepts had any real basis. Now that the first group of experimental data has been carefully studied, it appears that energy stored in phosphorus may be released as luminescence through a number of parallel internal channels. Distribution of energy between these channels varies with temperature in a way not yet understood. There is no indication that these channels can be correlated with any structure in the emission or absorption spectra of phosphors. Previously in the absence of adequate experimental data the possibility of multiple decay channels had been a subject only for speculation.

It is reasonable to suppose that a wider survey of both materials and temperature will discover a more complete model of the mechanism of phosphorescence. A semi-automatic phosphorometer is being built for this purpose.

(3) *Secondary Electron Emission.*—Research on secondary electron emission has been designed to obtain a better understanding of interactions between electrons and metal surfaces, and ultimately to investigate the properties of metal surfaces subjected to controlled contamination by gases such as oxygen and hydrogen.

Various properties of secondary electron emission — e.g. the angular distribution of paths of secondary electrons — will be measured in an ultra-high vacuum system. Design and construction of the apparatus and the ultra-high vacuum system is now almost complete.

(4) *Nuclear and Electronic Interactions in Molecular Solids.*—In the theory of molecular systems, it has been customary to assume that the motions of electrons and of atomic nuclei are independent. However, in the case of molecular solids, this assumption is not valid for treatment of electronically excited states involved in electronic energy transfer and optical emission and absorption. The theory of the interaction between electronic and nuclear motions is being developed to obtain a better theoretical description of these processes. The part of the theory relating to intramolecular vibrations is now well advanced. On the basis of the theory developed so far, it has been possible to clear up some apparently anomalous features of molecular crystal fluorescence.

(5) *Theoretical Studies of Metals.*—The theoretical tight-binding approximation is being applied to cubic metals to determine the range and directional properties of indirect exchange coupling, and also the effect of impurities upon the Knight shift observed in nuclear magnetic resonance studies of a pure metal. This method should give an explicit dependence of these quantities upon lattice structure, but their determination is much more cumbersome than the free electron approach.

(6) *Calculation of Potential Energy Curves.*—Techniques have been extended and improved for calculating the potential energy curves of diatomic molecules. It has been shown how these calculations may be combined with the analysis of band spectra to yield results which are much more accurate than those obtainable directly from theory or directly from spectra. This approach has led to an improved estimate of the dissociation energy of the BH radical, and its application to other systems is under consideration.

4. Spectroscopy

The Spectroscopy Section is concerned with the study of molecular structure and energetics by mass and optical spectroscopy, including infrared, Raman, visible, and ultraviolet (including the vacuum ultraviolet) spectroscopy. Studies of atomic spectroscopy are also undertaken with special reference to application of atomic absorption spectroscopy to chemical analysis, and to studies of the shape and fine structures of atomic spectral lines. The Spectroscopy Section is also responsible for development of specialized optical techniques.

(i) *Mass Spectroscopy*

(1) *New Mass Spectrometer.*—The 12 in. radius single-focusing 60°-sector instrument, on which the main construction was completed during 1959, has undergone an extended period of testing, to explore its possibilities in various fields of application. Ionization sources of several different designs have been constructed, to meet requirements of high mass resolution, high sensitivity, and other specialized purposes in electron-impact studies. It has been found possible

to obtain a clear separation of peaks differing in mass by one part in 4000, and when peaks are clearly resolved their masses can be measured to one part in 30,000.

Ease of demounting the vacuum system and the high pumping speed available have reduced the "down" time for replacing a filament or ion source to about 3 hr, a great improvement on other instruments. The unit method of construction used for the electronic circuitry has proved very satisfactory, minimizing the time spent on fault-finding or servicing. Sensitivity provided by the 16-stage multiplier has proved more than adequate, the limit of usability being set rather by "background" impurities.

A vacuum ultraviolet monochromator for use in conjunction with the new mass spectrometer is nearing completion.

The high resolution available using the new mass spectrometer has made possible its application to identification and determination of the structure of unknown molecules. Atomic weights of elements are not exactly whole numbers, and hence molecular weights of different compounds which are the same to the nearest whole number, differ when measurement is made to a higher order of accuracy. If the molecular weight of an unknown compound is measured sufficiently accurately, there is only one combination of atomic weights which add up to this total, and one mass measurement gives the empirical formula unequivocally. In the mass spectrometer the electron beam breaks up a molecule into fragments that depend on its structure, and the same technique can be used to determine the atomic constitution of these fragments.

Studies of this kind are being made, in collaboration with the Organic Chemistry Section, the Dairy Research Section, and the Division of Mineral Chemistry, of the structure of a plant alkaloid, of the identification of certain taints in cream, and of the products resulting from spontaneous catalysis on mineral-silicate surfaces respectively. In the second of these studies, gas-phase chromatography is being used with great advantage to separate various constituents, which are then transferred to the mass spectrometer for identification.

(2) *Ionization Efficiency Studies*.—Study of the threshold laws for different classes of ionization process has been extended to include double ionization of molecules by electron impact. Similarly to the rare gases, the ionization varies above threshold as the square of the excess electron energy. For molecules, however, autoionization processes appear to complicate the shape of the curves. A combined theoretical and experimental study of energy states of doubly charged homonuclear diatomic molecules has commenced.

A study of excitation induced by photon impact has been carried out in conjunction with the University of Chicago and the Argonne National Laboratory. For many molecules autoionization processes contribute significantly to the total ionization. The fact that processes leading to different degrees of ionization follow differing threshold laws has made it necessary to reconsider methods used to calculate ionization threshold energies. Measurements have been made for the multiply charged rare gases, and the new values for the higher degrees of charge are considerably different from those found earlier.

The theory of ionization efficiency curves has been extended to show that relative electronic transition probabilities can be obtained from the experimental data. Measurements of these probabilities have been made for a number of states of the rare gases krypton and xenon.

A study is being made of the kinetic energies of dissociation of fragment ions, using a radio-frequency pulse technique. This method promises to be more sensitive than other direct methods employed.

Experiments continued on use of electrostatic velocity analyses to obtain mono-energetic beams of electrons for ionization efficiency studies. Good energy resolution has been achieved, but current densities obtainable so far are too low.

(ii) *Optical Spectroscopy*

(1) *Vibrational Spectroscopy*.—From a comprehensive study of the Raman and infrared spectra of a series of *iso*thiocyanates, bands have been identified which are characteristic of an aliphatic or aromatic —NCS grouping. The diagnostic value of these bands has been strengthened by an analysis of the spectra of benzoyl *iso*thiocyanate and phenyl thiocyanate.

Microwave-powered Raman sources have been used to record Raman spectra excited by the red helium line at 7281 Å. Poor sensitivity of the infrared plates due to aging is one of the main factors in the long exposure required to record spectra at these wavelengths.

Raman spectra of the yellow liquids CCl_3SCl and CCl_3SF are under study at present.

(2) *Electronic Spectroscopy*.—Investigations of the visible absorption spectra of single crystals of copper and nickel complexes have enabled a critical analysis to be made of the theoretical calculations of the energy levels. In addition, a study of the ultraviolet absorption spectra in solution has led to a reformulation of the theory of metal-ligand bonds which incorporates, in some cases, the features of both Pauling's valence bond theory and the crystal field theory.

The free-electron model for calculation of electronic energy-levels of aromatic hydrocarbons has been applied to a number of ions and polar molecules. The model, as designed for non-polar molecules, still works satisfactorily for the lower energy levels of charged and polar molecules.

(3) *Atomic Spectroscopy*.—The technique of applying atomic absorption spectroscopy to chemical analysis, first developed by the Division, has been further extended. Good progress has been made in using the phenomenon of cathode-sputtering to produce atomic vapours directly from metal samples, thus avoiding the necessity of taking the samples into solution. The sputtering technique can be used to determine elements such as silicon which form refractory compounds in flames, and thus cannot be determined by the usual atomic absorption methods in which a flame is used to produce atoms from the solution to be analysed. Encouraging results have been obtained in applying the sputtering method to the determination of carbon in steel.

(4) *Specialized Optics.*—In spectral analyses of weak light sources under high dispersion, long exposure times are frequently necessary. A serious problem is then the maintenance of image stability in the presence of mechanical, thermal, and barometric pressure changes. A servo-mechanism for compensating image shifts in the echelle spectrograph has been designed; bench tests show stability of the order of 1 μ for periods up to 24 hr. Construction of the mechanism is nearly complete.

5. Instruments

The Instrument Section is responsible for development of new types of instruments, and for construction and maintenance of instruments for the Division and for other Divisions and Sections of the Chemical Research Laboratories.

A simple electronic unit has been constructed for recording intensity ratios in double-beam single-detector spectrophotometers. A novel method of controlling the gain of the photomultiplier detector is used to produce a constant-level reference output, permitting the ratio of reference to sample signal to be read directly on a simple meter or pen recorder.

A compensated indicator for use in atomic absorption spectroscopy has been constructed. The unit automatically compensates for changes in intensity of the light source. A twin-channel system is employed, the monitor channel being used to detect changes in light intensity and to apply correction to the sample channel by changing the gain of the photomultiplier detector. Changes of light intensity over a 200 : 1 range produce less than 1% deviation in the output of the compensated sample channel.

There has been further development in hollow-cathode spectral lamps, and these are now being manufactured commercially in Melbourne by Messrs. Ransley Glass Instruments.

The diffraction grating ruling engine is now properly housed on an anti-vibration mounting in a temperature-controlled room. Construction of the engine has proceeded to the point where all the major components are completed and the final hand fitting and testing are progressing.

6. Service and Collaborative Work

The Division has continued to make specialized facilities available to other Divisions and Sections of the Organization, research institutions, and industry. Some of the more important problems undertaken during the year are listed below.

(1) *Electron Microscopy.*—Examination of colloidal silver and silver iodide particles; studies of a virus disease of the Emperor Gum moth, of Murray Valley encephalitis, and influenza viruses; examination of nitrogen-fixing root nodules of soybean.

(2) *X-ray Diffraction.*—Studies of the phases and orientation in cetyl alcohol samples; examination of the corrosion products of lead; investigation of some polysaccharide samples; identification of a high-pressure black phosphorus allotrope.

(3) *Mass Spectroscopy.*—Analysis of: impurity in Geiger counter filling; hydrogen and sulphonyl fluoride samples; decomposition products of sulphonyl fluoride.

(4) *Optical Spectroscopy.*—Analysis of: aviation fuels; heat-absorbing glasses; copper alloys; dairy products.

Several workers from industry and the research laboratories have been trained in the techniques of atomic absorption spectroscopy, and the Division has received a large number of requests for advice on the scope of this new analytical method.

30

Division of Physical Chemistry

1. General

The Division of Physical Chemistry in Melbourne is one of the Divisions of the Chemical Research Laboratories (*see* Chapter 28). The Division undertakes basic and applied research in selected application of physical chemistry to problems of national and industrial importance.

The current research of the Division is concerned principally with: conservation of water in reservoirs and dams; control of bushfires; nucleation of ice formation in clouds; thermodynamics of liquid mixtures; chemical effects of very high pressures; and energetics and reaction mechanisms involved in certain chemical and biological processes.

Dr. K. L. Sutherland, formerly Chief of the Division, resigned during the year to accept appointment as Director of Research for the Colonial Sugar Refining Co. Ltd.

2. Water Conservation

Work continued on methods of maintaining surface films of cetyl alcohol on water storages, to reduce evaporative losses from them.

The "dusting" process, mentioned in the previous report, has been tested for nearly 12 months on two reservoirs located at Broken Hill and Mary Kathleen respectively. The process provides a simple and rapid method of applying the film, so that reductions in evaporation of about 50% are obtained in calm or near-calm weather. In its present form, however, the technique is unable to replenish satisfactorily film removed by wind and wave action, so that performance decreases as wind velocities increase above 5 m.p.h. For winds of 15 m.p.h. very little reduction is obtained. It is hoped to modify the process to provide greater resistance to wind action.

Some further work has been done on phase changes in cetyl alcohol produced by temperature varitions, and on influence of additives on phase changes. These changes influence the ability of cetyl alcohol to form surface films.

In small water storages there is sometimes present a natural surface film which coats the floating beads of cetyl alcohol and hinders spreading. The raft process is then ineffective, and an alternative technique is being sought.

3. Bushfire Research

The major project on bushfire research is basic study of the physics and chemistry of flame propagation with natural fuels. For this purpose a mobile laboratory has been equipped and used to measure in actual fires the levels of radiation and temperature that prevail. Data gathered thus are being used to design laboratory experiments similar to conditions existing in bushfires. At the same time variation of moisture contents of natural fuels with climatic conditions is being studied and related to fire hazard. Field and laboratory assessments of various chemicals as fire-proofing agents have continued.

Methods have been studied of reducing the dangers and discomforts to which rural firefighters are exposed. In all of this work the research team has enjoyed the cooperation of many organizations devoted to fire control.

4. Ice Nucleation

It has generally been considered that silver iodide promotes ice formation in a supercooled cloud by a sublimation process. This process requires particles to be approximately 1000 Å in diameter, and generators of silver iodide smoke have been designed on this basis.

Current work has shown however that, to be equally effective as ice nuclei, particles that nucleate freezing need be only 200 Å in diameter. In natural clouds particles of this size do, in fact, function as freezing nuclei. Therefore an increase in efficiency of more than 100-fold is theoretically possible if a generator could be designed to produce only these smaller particles.

Because the activity of silver iodide is critically dependent on particle size, the preparation of sols of uniform particle size is being undertaken. Such sols will provide the basis for the study of the effect of surface treatment on the activity of silver iodide particles as freezing nuclei.

A theoretical study has been made of the effect of topographical features, such as steps and pits, on the ability of otherwise plane surfaces to act as ice nuclei. Experimental work supports the finding that such features are preferred sites for nucleation, particularly when the nucleating substance exhibits a high contact angle against water.

5. Fluids Research

(1) *Properties of Liquids*.—Experimental and theoretical studies have been made of liquids and their mixtures to extend the present knowledge of liquid structure, and to develop methods for prediction of the physical properties and behaviour of technically important liquid mixtures.

A new apparatus has been developed for the precise measurement of heats of mixing, and methods have been developed for the direct measurement of volume changes on mixing.

Heats of mixing have been measured over the whole concentration range at 45, 35, and 25°C for eight alcohols in benzene solution. Volume changes on mixing have been measured as a function of concentration at 45, 35, and 25°C for mixtures of eight alcohols in benzene solution and for six systems containing acetone, nitromethane, or acetonitrile. Experimental thermodynamic data in the temperature range of 25–45°C for benzene solutions of four normal alcohols have been used to evaluate the best set of parameters in Barker's theory of associated solutions for this group of mixtures.

A new approach to the structure of liquids and compressed gases has been developed based on a disordered "tunnel" structure in which molecules are pictured as moving in tunnels, the walls of the tunnels being formed by neighbouring molecules. This picture of fluid structure is much more realistic than those previously used and has made possible theoretical calculations of the properties of simple liquids which give results in very good agreement with experimental data. This has led to advances in methods for predicting, correlating, and understanding the properties of liquids and compressed gases. This new approach has many applications in other problems concerning the structure of matter — for example, order-disorder properties of alloys.

(2) *Lurgi Brown Coal Tar*.—Work has been completed on determination of the composition of two neutral oil fractions of a Lurgi tar from the Morwell plant of the Gas and Fuel Corporation of Victoria. The neutral oil fraction boiling from 30 to 130°C was found to contain aromatics (78 wt.%), olefines (10%), paraffins (5%), and non-hydrocarbons (7%). The neutral oil fraction boiling from 130 to 172°C contained aromatics (67%), olefines (15%), paraffins (7%), and non-hydrocarbons (11%). The aromatics were mostly benzenes with short side chains, the olefines chiefly straight-chain alpha olefines, and the paraffins mainly *n*-alkanes. The non-hydrocarbons were mainly methyl-*n*-alkyl ketones and furanes with some thiophenes. In the two neutral oils 144 compounds were shown to be present, and more than half of these have been identified.

There were no known rapid methods for determining the composition of pyridine and quinoline bases contained in tar oils. Gas chromatographic methods have been studied by officers of the Organic Chemistry Section to find suitable stationary phases to effect a satisfactory separation. The method now developed by them has been applied to analysis of tar bases from the Lurgi gasification of Victorian brown coal. The simpler members of both series of bases may be thus analysed, but results for higher members are still not reliable.

6. High Pressure Laboratory

The work of the High Pressure Laboratory in Sydney is concerned with the influence of pressure on chemical reactions in liquids. Recent experiments there have shown that it is possible to change the course of some organic reactions by subjecting them to high pressure. For instance, an applied pressure of 2000 atmospheres doubles the relative yield of one of the two isomers formed by nitrating *m*-xylene. This is a novel effect and is one which might have industrial applications.

Explosions are being used to generate instantaneous pressures of nearly a million atmospheres, and techniques have been worked out to study chemical changes under these conditions. It has been found that the explosive compression of water transforms it into a very strong electrolyte and that the change occurs within one five-millionth of a second, a fact which bears on the theory of fast reactions. Under similar conditions, marked changes have been observed in the electronic spectrum of neodymium ions in water.

7. Photochemistry

Inquiry into possible methods for using solar energy in quantity continued. Theoretical consideration was given to the four main methods of conversion, i.e. chemical, thermoelectric, photovoltaic, and mechanical, and an experimental study was made of the mechanism involved in photolysis of water on crystal phosphor surfaces. The chemical approach, viz. generation of hydrogen gas from water, presents several severe limitations. Available thermoelectric devices that can convert with an efficiency of approximately 8% for a temperature differential of 300°C, are unlikely to be improved to beyond 10% efficiency. It has been shown that for this method, the ideal junction material will have to be one with a Seebeck potential of 200 μV/°C, specific electrical resistivity of 5×10^{3} ohm-cm, and a coefficient of thermal conductivity of 0.01, but no means are known at present to produce this ideal material or even approach it. Photovoltaic devices now operating at about 12% efficiency are likely to be improved to 14–15% by cutting down losses due to reflection and recombination of carriers. Mechanical conversion units, viz. steam engines and particularly hot-air engines, show most promise in the field of solar energy utilization, the latter being intrinsically capable of efficiencies of the order of 30–40%.

Experimental study of photochemical production of hydrogen peroxide by zinc oxides, zinc carbonates, and cadmium sulphides has shown the mechanism to be based on photoionization (i.e. separation of charges) requiring the presence of two types of centres, viz. electron donors (interstitial metal atoms or anion vacancies) and electron acceptors (traps consisting of oxygen, water, or carbon dioxide). It is suggested that photoionization may also play a more important role in photosynthesis than triplet excitation. Electrons raised into the conduction band rather than those responsible for fluorescence appear to be responsible for photochemical activity. None of the semiconductors tested so far offers any promise as a practical means of converting solar energy.

8. Semiconducting Organic Polymers

Work is continuing on synthesis of semiconducting organic polymers at moderate temperatures. A xanthene polymer has been prepared by fusing hydroquinone with pyromellitic anhydrite, phthalic anhydride, and zinc chloride in an inert atmosphere at 200–250°C. After thorough washing this had a specific electrical resistance of 7×10^3 ohm-cm which is less than that of crystalline organic semiconductors by a factor of at least 10^4. It has been possible to relate its p-type semiconductivity to the partial ionization of lactone rings in the polymer.

9. Enzyme Chemistry

Most of the fixed nitrogen in soils owes its origin to certain species of bacteria which, either free-living or in root nodules, convert gaseous nitrogen of the atmosphere to ammonia. Chemical industry is not able to achieve the fixation without resort to high temperatures and pressures. It is therefore of potential economic interest to investigate the means by which bacterial enzymes carry out the process at atmospheric pressure and temperature.

A study is being made of the enzymes concerned, and where these are too unstable, of related enzymes or metal-organic complexes with similar catalytic properties. One such enzyme is haemoglobin, which is closely related to the root nodule pigment now believed to perform a vital role in nitrogen fixation. Detailed investigation has been made of its oxidation reactions, at sites on the protein and the porphyrins as well as the iron atoms. The immediate oxidation product, methaemoglobin, can be oxidized further to yield three products, their principal absorption bands in the visible spectrum lying at 525, 545, and 585 mμ. It has been confirmed that the 545 mμ complex has one less electron per iron atom than methaemoglobin, and that its formation and properties fit the assumption of a ferryl ion structure containing tetravalent iron.

The 525 mμ complex is short-lived and more active as an intermediate in peroxide decomposition than the more stable 545 mμ complex. Its formation probably involves reversible oxidation of the porphyrin.

Division of Mineral Chemistry

1. General

The Division of Mineral Chemistry in Melbourne is one of the Divisions of the Chemical Research Laboratories (*see* Chapter 28). The Division is concerned with application of the principles of chemical research to the efficient and economic utilization of minerals and their derived products, whether these are metals or non-metals. In some instances the Division's research projects are financially sponsored by industrial establishments but in others, particularly the more fundamental investigations, this is not so. A wide range of projects is currently under investigation, including studies on the extraction and recovery of rarer metals such as gold, zirconium, and thorium. Attention has also been given to well-known industrial intermediates such as alumina. Some of the less common substances under investigation are concerned with nuclear energy requirements, and these form one part of a general program of assessment of Australian resources of useful derivatives of indigenous mineral substances.

2. Alumina

Considerable progress was made with the development of an acid process for the production of alumina from various raw materials. The conventional method of making alumina is by the alkaline (or Bayer) process using bauxite as the source mineral.

Much further detail has been gathered with regard to this acid process, which was first mentioned in the report for 1958–59. Preliminary costing has been carried out, using a flow sheet based on fully cyclic operation. Present indications are that reagent costs are considerably less than those for the conventional Bayer process, but that capital costs for the necessary corrosion-resistant equipment are high. Investigations are now being conducted with a view to reducing equipment costs by the use of different materials of construction and by adopting improved chemical techniques which would permit a greater output from a given size of plant.

The process has also been tested with clays and aluminous laterites and shows promise of being readily applicable to these materials, which cannot be economically treated by the alkaline Bayer process. To this end, a survey is being conducted on various low-grade bauxites from Australian localities, to ensure that all stages of the process can be satisfactorily applied. Other aspects of the work are connected with the effect of alkali metals on the overall cyclic process, since these have caused undesirable contamination of the final product (alumina) in most other acid processes. The recovery of valuable minor constituents from the aluminium ores is also being studied, since in many instances these could build up to useful concentrations in the C.S.I.R.O. process.

3. Thorium

Early studies in the Division on the extraction of thorium from monazite resulted in an economic process for recovering rare earths and thorium. The recent discovery in Canada of a large source of cheaply recoverable thorium has emphasized the need for a more direct, lower-cost process if thorium is to be extracted from local resources at a price even approximately competitive with imported material. Technical and economic aspects of the problem have therefore been re-examined and a promising new process developed. The new process is characterized by a minimum number of operations for extraction of thorium and by the use of the cheapest available chemicals. Rare earth by-products need not be processed unless a suitable market is developed. Ample information is now available to produce thorium in Australia as soon as a demand arises.

An investigation of the lower valent states of thorium has been started. It is hoped to prepare compounds of thorium in its lower valent states sufficiently stable to allow a general study of these states. Trivalent thorium in particular may prove to have unique properties, behaving in some of its compounds like trivalent zirconium, and in others like trivalent uranium. This behaviour has potential value in separation and decontamination processes for thorium. Information of general application in the chemistry of heavy metals may be also obtained from this study.

4. Germanium

A project involving development of a suitable process for recovery of germanium from domestic sources has been completed. Certain selected power-station flue dusts of germanium content ranging from 4 to 8 oz per ton can be treated by the new process (detailed in the previous report) and should local production be required, amounts of up to 0.5 tons per annum of metal, currently valued at £4 an ounce, would be available.

5. Preparation of Pure Metals by the "Iodide" Process

Developments in technology and metallurgy continue to emphasize the need for supply of metals in a high state of purity. Preliminary work has therefore been done to extend the carbide-iodide process, which was initially developed in the

Division for the supply of high purity thorium, to the preparation of other pure metals. The synthesis and properties of a number of carbides have been investigated. Several carbides have been synthesized directly from phosphates.

The preparation of thorium on a half-pound scale has been examined. Factors influencing the rate of deposition have been studied in detail and the design of an all-metal reactor to operate at 600°C has been completed.

Electrical methods of accelerating the thermal decomposition of metal iodide vapours have been explored in some detail. Although many phenomena of potential use in other investigations have been observed, it has not yet been found possible to accelerate the rate of deposition of solid metal by electrical means.

6. Hydrometallurgy of Gold

Work has been continued with the financial support of the Chamber of Mines of Western Australia acting on behalf of all its gold-producing members. Inefficiency in the process of cyanidation may occur as a result of a diminution in the supply of dissolved oxygen or of "free" (i.e. uncomplexed) cyanide, the diminution being caused in both instances by impurities present in the ores. There is no doubt that substantial savings would be effected if the mines had methods of automatically recording the dissolved oxygen and the free cyanide in the process stream. The polarographic method, which depends on a measurement of current, lends itself to continuous recording and so considerable effort has been put into the problem of determining cyanide by this method in the presence of the many other substances found in cyanide plant solutions. The polarographic method also is one of the few which will determine the instantaneous or equilibrium amounts of free cyanide in the presence of complex cyanides. A procedure for the batchwise determination of dissolved oxygen which has marked advantages over other methods has also been devised. Both methods will shortly be given a trial on a small pilot plant erected at the Kalgoorlie School of Mines with the assistance of the C.S.I.R.O. and every section which is housed there.

7. Electrode Processes

A study of the rate determining processes in the cathodic evolution of hydrogen on iron, tungsten, and platinum in acid solution has been made by an officer of the Division working with Professor J. O'M. Bockris at the University of Pennsylvania. The use of water and deuterium electrolytes of high purity showed differences in rates of hydrogen and deuterium evolution on the same metal. A theoretical treatment based on the adsorbed hydrogen being mobile on the surface showed that the experimental results correspond to slow discharge of protons on to the metal surface for iron, slow discharge of protons on to an adsorbed hydrogen atom for tungsten, and a slow combination of adsorbed hydrogen atoms for platinum. When combined with the isotopic separation factor the relative rates in pure hydrogen and deuterium solutions provide a means of determining both the rate determining step and the reaction path. On iron it suggests slow discharge of a proton followed by a fast recombination of adsorbed atoms, and the publshed results on mercury suggest slow discharge of a proton on to the metal followed by a fast proton discharge on to an adsorbed hydrogen atom.

8. Gas Diffusion Cells

Experiments have been begun to study the reaction mechanisms which occur when gases such as hydrogen and oxygen are passed on to porous electrodes arranged to form a galvanic cell. A number of metal and metal oxide catalysts have been examined, as well as several methods of depositing them on the internal surfaces of the electrodes. For use as electrolytes both strongly acid and strongly alkaline media have been studied. The current densities for any given polarization obtained from laboratory model cells are comparable with those quoted in the literature.

9. Zirconium

The fundamental study of the decomposition of zircon has led to pilot-plant tests of a continuous treatment of the sand in a rotary kiln; current investigations are aimed at the production of low-cost zirconium chemicals from the kiln product. Part of this program is concerned with the significance of zirconium polymerization in aqueous solution.

The study of the lower halides of zirconium and hafnium has been continued with a view to providing fundamental data for developments in zirconium technology. The thermodynamic properties of zirconium trichloride have been measured, and a potentiometric investigation of the reduction of zirconium tetrachloride by zirconium in a fused salt has been commenced.

10. Reactions in Electromagnetic Fields

A study was made of the phenomenon of polymerization induced by high-frequency electromagetic fields. A wide variety of compounds yield free radicals and atoms when subjected to such fields, and the subsequent interaction of these results in new substances having entirely different properties to the original materials. Some of these properties have been investigated and methods for modifying them have been found.

11. Chemical Crystallography

Work is continuing on the study of complex titanates and niobates which are chemically related to the quasi-crystalline metamict minerals. The crystal structures of three compounds within the system TiO_2-Nb_2O_5 have been completed. All contain "holes" which are suitable for occupancy by additional metal ions of a different kind. Experiments are in progress to determine the effects of alkali metal ions in these positions upon the structure, and to ascertain whether or not additional disorder can be induced by this means. A new kind of quaternary compound $KTiNbO_5$ has been formed, and is being examined by X-ray and dielectric absorption studies.

The effects of a large percentage of anion vacancies upon solids are being examined, in collaboration with a guest worker, with emphasis upon the technically important perovskite structure. The compounds $K_2Ti_2O_5$ and $Na_2Ti_3O_7$ have been prepared, and preliminary results show that two different mechanisms, each involving a major reshuffle of ions, can be identified.

An examination of tungsten trioxide whisker growths was undertaken in collaboration with the Cement and Refractories Section.

12. Graphite

In connexion with the investigations on graphite and its chemical derivatives a new process for decreasing the porosity of certain forms of graphitic carbon and rendering them denser was devised and studied. This work has a bearing on the requirements of graphite used in nuclear reactors.

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Cement and Refractories Section

1. General

The Cement and Refractories Section in Melbourne (formerly the Cement and Ceramics Section) is one of the Sections of the Chemical Research Laboratories (*see* Chapter 28). The Section undertakes research on the basic chemistry of cement, concrete, and refractories essential in various industries.

The Division of Building Research undertakes basic research on concrete as a building material and investigates the industrial potentialities of Australian clays and clay products (*see* Chapter 23).

The current program of the Cement and Refractories Section includes projects on cements and concretes, subsidized by the Cement and Concrete Association of Australia, and on the fouling of boilers by brown coal ash, subsidized by three major users of Victorian brown coal.

Investigations of potential importance to a number of industries, but not directly subsidized, include such diverse projects as fabrication of special refractories and hard materials, and studies on the water phase of a liquid crystal system.

The Section is no longer specifically responsible for research into the problems of orthodox ceramic industries. The Adelaide Ceramics Laboratory has been transferred to the Division of Building Research and is now seconded to the Australian Mineral Development Laboratories.

2. Cement and Concrete

(1) *Cement Characteristics.*—Fundamental studies on the mechanism of hydration and development of strength in cements continued.

Rates of hydration and strength gain of cement paste have been shown to follow a normal Arrhenius rate expression within certain limits. Apparent activation energies for these processes are higher than those reported for concretes by previous workers.

Effects of alkalis on development of strength in cement pastes conform to a complex but coherent picture, an account of which has been published. All

Australian cements studied show flexural strength maxima at an optimum alkali content. This is an interesting contrast with the decrease in compressive strength, which generally occurs as alkali is introduced.

The action of chemicals which specifically retard or accelerate the hardening of cement products has been the subject of detailed investigation. Retarders function by inhibiting hydration. New accelerating agents have been found, which differ from those in current use by not inducing corrosion of reinforcements. Economic factors at present militate against the general use of these agents.

(2) *Cement Manufacture*.—Rapid analytical methods, based on the use of the spectrophotometer, are now being used in several Australian plants for control of cement composition. Aspects of the method are being re-examined, in view of minor difficulties which have arisen in the application of the method under plant conditions.

Studies of milling processes used in cement production suggested methods of reducing ball and liner corrosion in wet-process mills, and of increasing throughput by modifications in the design of dry-process ball mills. Free-flowing characteristics of dry cements have been improved by conditioning the powders with special vapour-phase agents, adsorption of which reduces intergrain adhesion and adhesion of the powder to internal surfaces of milling and transporting equipment.

(3) *Concrete*.—Further examination of factors involved in determining concrete strength has shown that the size of aggregate used is important. Bond between paste and aggregate falls progressively with increase in aggregate size above the "half-inch" grade.

The mechanism of bond failure causing this size effect appears to involve differential movements at interfaces between the cement matrix and aggregate.

With the demonstration of this effect, it is now possible to understand some of the anomalous behaviour of large-aggregate concretes used in dam construction, particularly in regard to break patterns and strengths.

Continued study of factors favouring fine-bubble formation in air-entrained concrete has shown that bubble size may be precisely controlled by use of an extra additive, and by standardizing mixing conditions. Entrainment of these fine bubbles should permit reduction in the total quantity of entrained air needed to confer the usual benefits, and simplify control of air-entrainment in the field.

Use of epoxy-resin films to enhance the bond between reinforcing steel and concrete has been further investigated. The reduction in slip of reinforcement under stress is very marked with this technique, a point of some interest in prestressed concrete practice. Practical trials of the technique are being carried out by the Snowy Mountains Hydro-Electric Authority.

3. Refractories

Investigations are largely concerned with basic refractories derived from magnesite, chromite, dolomite, and lime, of the types used in the cement and steel industries, and with new super-duty refractory and hard materials based on sintered or metal-bonded oxides, carbides, and silicides.

Study of the characteristics of "chemically bonded magnesite" refractories is in progress. Bricks of this type are reported to give highly variable results in service in certain industries.

High-quality magnesia shapes have been produced by new slip-casting and sintering techniques which have aroused interest overseas.

Further progress has been made in the stabilization of dolomite and lime against hydration. Useful effects may be obtained with additions of stabilizing elements at a level which could prove economic in production of stable bricks for steel-making processes of the L.D. type.

High-grade alumina refractories have received further attention, and a related project on production of alumina machine-tool tips has given encouraging results. Cutting tips hot-pressed from a special variety of alumina proved comparable with the best available imported alumina tips.

A new approach to the problem of forming gas-tight seals between refractory bodies and metals has been made possible by further development of the "reaction-pressing" technique. The seals comprise intermetallic compounds, such as silicides, formed *in situ* by subjecting the elements to elevated temperatures under shear stress.

Slip-cast chromium-alumina cermets have been improved by increasing the density and degree of dispersion of the slips used. Silver-alumina cermets of high strength have been produced by infiltration of the molten metal into a skeleton of the oxide phase. The extent of internal strain effects in the system titanium carbide–nickel has been investigated.

Various oxide, sulphide, and carbide systems have been studied by thermal, optical, and X-ray diffraction methods. Zirconium carbide has been investigated for use in rocket nozzles, and zirconia and zirconates have been fabricated into special refractories. A new compound of zirconium, tungsten, and oxygen has been prepared and described. Tungsten oxide "whiskers" have been shown to have a "tungsten bronze" structure with an ordered superlattice of molybdenum. Changes in lattice spacing and colour throughout the alumina-chromia system have been examined, and the discontinuity postulated by previous workers at 8% Cr_2O_3 shown not to exist. Colour change from red (ruby) to green (Cr_2O_3) is due to a gradual shift of the absorption band structure with increasing replacement of aluminium by chromium.

Structural work on the chalcogenides of thorium has been completed, and an investigation on the chalcogenides of niobium and tantalum commenced.

4. Brown Coal Ash

Survey of ash component distribution through the Morwell brown coal seam has been completed and results issued as "ash contour maps" of the field. The pattern of occurrence of each component can be worked out in a general way, both in plan and in depth, from the series of about 200 such "maps". Of the main components involved in boiler deposit formation, sodium is concentrated near the surface with relatively small amounts at depth, whereas calcium is found in quantity throughout, sometimes with a maximum near the centre of the seam.

Detailed examination of deposits formed in boilers using brown coals of various types has suggested that calcium sulphate may be as important as sodium sulphate in causing fouling.

5. Clay Minerals

Further attempts have been made to beneficiate, by chemical and physical methods, bentonites from recently discovered deposits in Victoria and New South Wales. Present limitations on their effectiveness as decolourizing agents and on their ease of dispersion suggest that these local bentonites will not generally replace imported materials.

Fundamental study of vermiculite, a clay mineral obtainable in large crystals, has continued, special attention being given to the water layers which may be intercalated between adjacent "silicate sheets" in the crystal structure. By suitable treatment, a flake of vermiculite may be swollen, unidimensionally, to 50 times its original thickness by absorption of water without loss of orientation of the silicate sheets, which suggests that the imbibed water is in an "ordered" state, possibly due to the presence of "icebergs" of the Frank-Evans type. The system may be regarded as a liquid crystal of a relatively simple type, providing an opportunity for the study of the electrical and thermodynamic properties of quasi-crystalline water. Results obtained indicate some analogies with biological systems.

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Chemical Engineering Section

1. General

The Chemical Engineering Section is one of the Sections of the Chemical Research Laboratories (*see* Chapter 28). The Section investigates techniques and processing in selected fields of chemical engineering.

Current projects being undertaken by the Section include: direct hydrogenation of brown coal to give a methane-rich gas; application of fluidization to mineral processing; studies of unit operations relating to "solids processing"; desalting of brackish waters and sea-waters; and studies of mass tranfer and reaction rate kinetics.

The Process Equipment Laboratory has continued to provide a valuable service, both to the Chemical Research Laboratories as a whole, and to outside institutions and firms. Approximately 30 projects were undertaken for outside firms and Government departments, and more than 60 technical enquiries, some involving investigations, were also handled.

2. Utilization of Brown Coal

(1) *Gasification of Brown Coal with Hydrogen.*—A new experimental plant for hydrogenation of brown coal employing a 20 ft deep fluidized bed reactor has been built and is about to be commissioned. The reactor is baffled to give essentially counter-current flow of the coal and hydrogenating gas. The design is based on results obtained with the earlier shallow-bed cocurrent reactor, which established optimum conditions for hydrogenation of brown coal to methane. The object of this design is to produce gas of high methane content, and to achieve simultaneously a degree of gasification sufficiently high to make the system thermally autogenous.

A series of experiments has been performed in a transparent model reactor to determine operating characteristics of deep baffled fluidized beds, and to develop instrumentation for the above plant.

(2) *Carbon Gasification Reactions.*—Study of reaction between carbon and carbon dioxide at pressures up to 40 atmospheres and temperatures in the range

790–870°C has revealed kinetic features analogous to those found for the carbon-steam system. The retarding effect of carbon monoxide is lessened as the carbon dioxide partial pressure is increased, and a new kinetic scheme has been suggested to account for this observation. Preliminary study of the reverse reaction indicated that this may be more complex than expected.

Experimental evidence has now been accumulated to show that reactivity of carbons is a function of the amounts of chemically combined hydrogen and oxygen present, and is inversely related to the hydrogen : oxygen ratio. In this connexion chemically bound oxygen must be distinguished from that which is chemisorbed. There is at present no definite evidence that reactivity is connected with a particular type of chemical group in the carbon. These results are in agreement with the observed difference in behaviour between artificial chars prepared at temperatures of 630–1950°C and graphite; further supporting evidence has also been obtained from work on the gasification of carbons with atomic species and dissociated gases, an investigation made jointly with the Division of Mineral Chemistry.

Gasification of carbon with hydrogen in a packed bed was studied theoretically under both isothermal and adiabatic conditions. Satisfactory solutions have been obtained by consideration of both chemical and physical processes taking place, and results are in close agreement with experimental data.

3. Process Development

(1) *Recovery of Tin from Low-Grade Sulphide Ores.*—Investigation has started into the possibility of devising new and more efficient methods of recovering tin from low-grade pyrrhotite ores, substantial deposits of which occur in the West Coast area of Tasmania.

On heating the ore to 850–900°C labile sulphur from the pyrrhotite converts embedded cassiterite to tin sulphide which then volatilizes. Efficient removal of tin from the ore has been achieved in this way. This effect may be exploitable in practice by a two-stage roasting process, although further work is needed on collection of resulting tin fume and its purification from arsenic and other contaminants.

Low temperature heating (i.e. up to 300°C) caused extensive intercrystalline cracking in the pyrrhotite which facilitated release of cassiterite grains on light grinding. Since the magnetic properties of pyrrhotite are enhanced by such treatment, the pyrrhotite (and some gangue minerals) can be efficiently removed by magnetic separation, leaving the tin in a non-magnetic quartz-cassiterite fraction. The optimum conditions for this process and its applicability to the various ore types available are being established.

(2) *Reduction of Iron Ore in Fluidized Beds.*—In collaboration with a Colombo Plan Fellow, a study is being made of the reduction of iron ore with hydrogen in a fluidized bed reactor. Particular attention is being given to factors which cause agglomeration in the reactor.

(3) *Process Evaluation*.—On the basis of process data obtained in a previous investigation, an economic appraisal of the Gaskin-Ringwood process for production of rutile from ilmenite has been made.

Assistance has been given to the Division of Mineral Chemistry in the preparation of process flow sheets, preliminary design of equipment, and cost studies for evaluation of the acid alumina process.

Possible methods of combining coal hydrogenation with other types of gasification systems have been considered.

4. Solids Processing

(1) *Cyclone Elutriator*.—By using a small hydraulic cyclone with a suitable sample container connected to the apex opening, a highly efficient batch elutriator has been developed for particle sizing in the subsieve range. By using quartz powders, precise separations have been obtained at selected size intervals between 40 and 8 μ, and there is evidence that this range could be further extended.

(2) *Ball Mill Grinding Circuits*.—A small-scale grinding circuit has been designed to investigate the dynamic behaviour of grinding circuits and possible methods of automatic control of such circuits. Construction of this equipment is well advanced.

(3) *Non-Newtonian Mixing*.—A laboratory-scale extruder-mixer has been designed and built to provide accurate measurement of fundamental mixing characteristics of non-Newtonian materials, such as plastics, doughs, and rubbers. Progress has been made in the search for a measure of "mixedness", suitable for the correlation of power input data and mixing efficiency.

New methods have been successfully tried for assessment of the efficiency of mixing of thick slurries. Larger-scale equipment is now under construction to permit more detailed examination of the mixing characteristics of such materials under a wide variety of conditions.

(4) *Gypsum Dissolution Machine*.—In conjunction with the Engineering Section, Highett (*see* Chapter 16, Section 16), and the Regional Pastoral Laboratory, Deniliquin (*see* Chapter 3, Section 13), a prototype trailer-mounted machine, based on the use of hydraulic cyclones, was developed for continuous dissolution of gypsum in irrigation water. Dissolution efficiencies of approximately 80% were achieved for water flow rates up to 2 cu. ft. per sec with gypsum concentrations up to 20 m-equiv. per l. (i.e. two-thirds of saturation). Field tests were highly successful and a simple version, utilizing a 44-gal drum as the cyclone, was designed for construction by farmers.

A provisional Australian patent application (No. 53666/59) has been filed.

5. Desalination of Water

The spray evaporation test unit referred to in the Eleventh Annual Report has now been operated for several hundred hours using tap-water, synthetic-brine, and sea-water feeds. Results confirm that exceptionally high heat transfer coefficients are obtainable with this system, overall values up to 4000 P.C.U./hr ft^2 °C having been recorded between condensing steam and boiling water with clean heat transfer surfaces and with oleic acid as a dropwise promoter on the steam side. On the other hand, it was found that this evaporator posesses no advantage over conventional types in regard to scale-forming characteristics. Untreated sea-water at 100°C gave a rapid deposition of alkaline scale (magnesium hydroxide and calcium carbonate). A similar result was obtained with "deaerated" sea-water, i.e. water held at a temperature about 10°C higher than the maximum in the evaporator to decompose bicarbonates.

Further tests were made with a sea-water feed acidified to pH 4.0 with hydrochloric acid to destroy bicarbonates. No scaling appeared after 40 hr continous operation at a maximum temperature of 116°C; a similar result has recently been reported by workers in the U.S.A. Recycling of the concentrated liquor gave a calcium sulphate scale when the concentration factor, expressed as the ratio of the feed to the residual brine, reached 1.8.

Economic study has been completed of large-scale combined power and desalination plants, based on the United Kingdom type of gas-cooled nuclear reactor in conjunction with proven types of flash evaporator. The largest installation considered, employing a 1000 MW (thermal) reactor, would produce 80 million gallons of water per day, i.e. enough for a population of about 500,000 persons, together with 63 MW of surplus electric power. The capital cost of such an installation has been estimated as about £A.88,000,000, and the operating cost as 7.9 shillings (Aust.) per 1000 gal with a power credit of 0.80*d*. per kWh sent out. Such an installation represents the most efficient type of plant which could be built at the present time.

6. Fluid Dynamics of Two-Phase Liquid Systems

The experimental glass-sided flow channel has now been completed and operated satisfactorily. Methods being studied for measurement of very low liquid velocities include optical and photographic methods of observing the movement of small particles or bubbles. A liquid differential pressure gauge is now being developed which is sensitive to differential pressure of the order of 10^{-3} in. water gauge, and could be used in conjunction with micro-Pitot tubes.

7. Process Equipment Laboratory

In addition to supplying the requirements of the Chemical Research Laboratories as a whole, this laboratory provides a range of chemical plant equipment available for use by other Government Departments and private firms. During the current year the Laboratory handled 13 projects for other Sections and Divisions of the Laboratories and other Government departments, and 21 projects for industry, the latter using staff provided by the companies themselves.

The following major projects were undertaken by the staff of the Laboratory:

(1) *Dyeing of Wool.*—Assistance is being given to the Division of Protein Chemistry in the development of a new process for dyeing wool. An experimental unit is being operated to test a new continuous counter-current method for dyeing wool and removal of formic acid after dyeing.

(2) *Recovery of Formic Acid.*—A design study was made to evaluate the overall cost of recovering formic acid from dilute aqueous solutions produced by the dyeing process under consideration. A pilot-plant distillation column was erected to recover formic acid from the dyeing unit.

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Organic Chemistry Section

1. General

The Organic Chemistry Section in Melbourne is one of the Sections of the Chemical Research Laboratories (*see* Chapter 28). The Section investigates potential organic raw materials, of Australian origin, for the chemical industry, and undertakes collaborative studies on biological problems of national importance. The Section also recognizes a general responsibility to the practice of organic chemistry in Australia, particularly in other C.S.I.R.O. laboratories. In the past this has been met mainly by the operation, jointly with the University of Melbourne, of the Microanalytical Laboratory, and by the provision of plant material for university chemists. In addition, the facilities of the Section's large-scale laboratory are available for use by other Divisions.

The work of the Microanalytical Laboratory continues to expand. Over 9000 analyses were carried out this year with the same staff needed 5 years ago to deal with less than half the number.

Representatives of Queensland cane-growers' and sugar-producers' associations and related experimental stations approached C.S.I.R.O., suggesting work be undertaken by the Organic Chemistry Section on non-food uses for sugar. Much work has been done overseas in this field of sucrochemistry, and there is no sign that commercial results will provide a market commensurate with the sugar surpluses frequently available.

Some 200 requests for plant material were met by the Section's field botanist in amounts ranging from a few pounds to a ton. In this work the Section has had, as in the past, the cooperation of State Departments of Forestry and State herbaria; this help is gratefully acknowledged.

2. Wool Wax

Gas chromatography has been used in a thorough analysis of the hydrolysed wax. Over one hundred new components have been found among the alkaloic acids, α- and ω-hydroxy acids, mono- and dihydric alcohols, and hydrocarbons present in the wax, in addition to the 60 previously known. Quantitative figures, previously available only for the alkanoic acids, have now been obtained for all components. The discoloration and the autoxidation of wool wax on exposure to heat have been further investigated.

From lanosterol a series of compounds analogous to the bile acids has been prepared for examination of their effect on serum cholesterol. Some polyoxygenated carboxylic acid derivatives which may be regarded as analogues of cephalosporin P or helvolic acid have also been prepared from lanosterol for antibiotic screening and for tumour-inhibiting and hormonal activity.

Study of long-range effects in the lanosterol series has been continued. Exocyclic methylene groups were substituted for carbonyl oxygen for comparison of their effects on the rate of hydrolysis of distant sterically hindered acetoxy groups. The methylene group has a facilitating action, but this is weaker than that of a carbonyl.

Investigation was made of the reported conversion of lanostane-3,7,11-trione into an isomer by methanolic alkali. The product was found to be a disubstituted methane formed by condensation at the 2- position of two molecules of lanostanetrione with one of formaldehyde. The latter may be present as an impurity in the methanol or arise by autoxidation. The reaction was shown to occur readily with other steroidal 3-ketones.

Lactones of δ-hydroxy acids have been reported to occur in wool wax acids after treatment with aqueous ethanolic hydrochloric acid. If present these would have arisen from a novel type of acid overlooked by other workers. However, repetition of the published work produced a neutral fraction consisting only of ethyl esters of known acids.

3. Sugar Cane Wax

Investigations on the chemistry of sugar cane cuticle wax have now shown that the large unsaponifiable fraction from the wax, most of which cannot be distilled, is largely composed of artefacts. The wax itself has an unusual composition, consisting of polymeric aldehydes, alcohols, hydrocarbons, and some free acids. On distillation a high yield of long-chain aldehydes is obtained. Each of the classes of compound present in the cuticle wax has been separated and converted into a form suitable for examination by gas chromatography, to determine the percentage chain length distribution for each type of compound present. There is no evidence for the presence in either the cuticle wax or the solvent-refined mud wax of esters or of any polyfunctional compounds such as hydroxy acids or diols, which, as in Carnauba wax, confer desirable properties.

Chemical examination has also been made of sugar cane wax recovered from filter mud at the North Eton sugar mill and refined by a solvent fractionation process. It has been shown that considerable chemical alteration of the wax takes place under these conditions.

4. Long Chain Compounds

(1) *Unsaturated Long-Chain Compounds as Insecticides.*—Work continued on the synthesis of polyunsaturated *iso*butylamides related to the naturally occurring insecticides *neo*herculin and affinin. The synthetic compounds incorporate the system $-(CH=CH)_n.CH_2CH_2.(CH=CH)_m.CONHBu$. Promising activity (against the housefly *Musca domestica*) has been found when $n = m = 2$ and the spatial arrangement is *trans*-2, *trans*-4, *trans*-8-*cis*-10, and *trans*-2, *trans*-4, *cis*-8, *cis*-10 in a chain length of C_{16}. Such compounds are unstable in air and light, polymerizing in the solid state in a matter of hours at room temperature. An attempt was made to overcome this instability by replacing one or both of the diene groups by benzene rings. The activity of the commercially available *N*,*N*-diethyl *m*-toluamide as an insecticide and repellent is some justification for this substitution. Results are not yet fully available but appear unpromising. Fourteen new amides have been submitted for testing over the past year.

(2) *Naturally Occurring Acetylenic Fats.*—Seven species of the order Santalales have been examined. Most of these species were found to contain varying proportions of four acetylenic glycerides, mainly in the roots and stems. The exception is *Balanophora fungosa*, which contains no conjugated polyunsaturated acids. The glycerides are of the following acids:

octadeca-*trans*-13-en-9,11-diynoic acid;
octadeca-*trans*-11-en-9-ynoic acid (ximenynic acid);
octadeca-*trans*-11-*trans*-13-dien-9-ynoic acid;
octadeca-*trans*-*trans*-dienediynoic acid (probably 9,11-diene-13,15-diyne).

The last two of these acids have never before been found in nature. Occurrence of these four acids as glycerides is unusual; the only other reported sources of acetylenic glycerides have been the seed oils of certain members of the Simarubaceae.

(3) *Structure of Wax Components.*—As an outcome of the investigation of the branched-chain acids of tubercle bacillus wax, two methods briefly reported last year have been further developed.

The first, originally devised to investigate the acids of tubercle wax, has now been applied generally to the examination of wax constituents. This consists of the separation of the constituents into classes (hydrocarbons, alcohols, diols, acids, and hydroxy acids) followed by the quantitative reduction of the oxygenated constituents to the corresponding mixtures of hydrocarbons. These and the hydrocarbons originally present are then examined by gas chromatography. Since the hydrocarbons are stable and elute easily, investigation of compounds of chain-lengths up to C_{40} is possible. The method, by which a wax can be thoroughly investigated in several weeks, has been applied to the four economically important waxes, wool wax, sugar cane wax, beeswax, and Carnauba wax, and also to the wax from the Queensland grass, *Leptochloa digitata*.

A second method, for the determintion of the structure of branched-chain fatty acids, is based on the discovery that these are extensively degraded by oxidation with potassium permanganate in acetone, the point of attack being the carbon atom adjacent to the carboxyl group. This produces a series of acids of diminishing carbon number. Where a branch occurs the acid series is interrupted and a methyl ketone is produced. Gas chromatographic examination of the ketone(s) and methylated acids gives clear evidence for the location of the branches. As previously reported, this method was used to investigate the structure of the two principal branched chain acids C_{25} and C_{27} phthienoic, both of which have methyl branches in the 2, 4, and 6 positions. Recently the method was modified to establish the structure of relatively impure acids, and 2,4,6,8-tetramethyl octacosanoic acid was shown to be the major constituent of the higher molecular weight saturated tubercule acids.

German workers have shown that the liquid preen gland wax of the goose is of most unusual composition, consisting almost entirely of the octadecyl ester of a branched C_{14} acid whose structure they did not determine. By a further modification of the above method this acid (75% of the total) has been shown to have the structure 2,4,6,8-tetramethyldecanoic acid, while a smaller amount (10%) of a C_{15} acid is present, the latter being 2,4,6,8-tetramethylundecanoic acid.

5. Brown Coal Tar

Work on gas-chromatographic methods for analysis of pyridine and quinoline bases present in brown coal tars is described with related work in the report of the Division of Physical Chemistry (*see* Chapter 30, Section 5).

6. Phytochemical Survey

Chemical and pharmacological screening of Australian plants continued along the lines of the previous year, but with a change of emphasis towards less investigated families. An interesting outcome has been the discovery, for the first time, of alkaloids in the family Moraceae. Several native species of this family have given positive results, and the alkaloids so far isolated appear to belong to a novel class. Some of them exhibit a degree of physiological activity.

The bulk of general pharmacological testing has, as before, been undertaken by Smith, Kline, and French Laboratories. Although several plant species warranted detailed investigation, to date no substance of outstanding therapeutical value has emerged. From the point of view of the survey as a whole, however, it is noteworthy that a species now being investigated in the University of Sydney was of sufficient interest to warrant extensive tests of the main alkaloid and of a number of derivatives. To further this work extraction of 2 tons of the plant was carried out in the Section.

Materials were also submitted to the United States Cancer Chemotherapy National Service Center and to the Victorian Cancer Institute Board for antitumour testing; a number of plant extracts were screened for anthelmintic activity, and the collaborative investigation with the Division of Animal Physiology of plants allegedly used in the western Pacific area for fertility control is now in full swing.

This testing, financed by a grant from The Population Council, Inc., is now proceeding smoothly, using rats as test animals. Mice were employed for some time, but proved unsatisfactory, so that extracts of a number of plants had to be retested.

Chemical studies on *Cryptocarya pleurosperma* have been concluded with the synthesis of the leaf-alkaloid pleurospermine, the structure of which suggests that it is a partly methylated intermediate in the biogenesis of cryptopleurine. Work on *Ochrosia poweri* is well advanced, the main features of the three major alkaloids having been determined during the year. Progress has been made with the difficult structural problems associated with the alkaloids of *Kopsia longiflora*, in spite of continuing shortages of plant material.

Progress has also been made with the separation and determination of structure of the labile water-soluble quaternary bases of *Lunasia quercifolia*. A study of the infrared spectra of artefacts arising from these substances has been carried out in collaboration with the Division of Chemical Physics (*see* Chapter 29, Section 4).

Volume I of a Phytochemical Register of Australian Plants was published this year. This volume consists of a record of chemical identification of plant constituents published in Australian periodicals. Subsequent volumes will deal with overseas publications. Collection of information was carried out on a voluntary basis by chemists in universities and C.S.I.R.O. laboratories, and the information was collated, checked, and prepared for publication in the Section. Nearly 300 copies were distributed to institutions throughout the world concerned with the study of plant chemistry, and additional requests are continually being received.

7. Stock Poison Plants

The principal field of activity in relation to stock poisoning continues to be liver-damaging pyrrolizidine alkaloids.

Structure of sarracine, the main alkaloid present in *Senecio mikanioides*, has been elucidated, nuclear magnetic resonance spectra confirming the structure of sarracenic acid. Mikanecic acid, previously isolated from this plant, was shown to be an artefact produced by the action of alkali on sarracenic acid. The structure of mikanecic acid was confirmed by synthesis. Work has been completed on the decomposition products of lasiocarpic acid in dilute and concentrated hydrochloric acid. A new alkaloid isolated in 0.35% yield from *Heliotropium indicum* has been shown to be the (−)trachelanthic acid ester of retronecine, unusual in two respects, in that it is the first occurrence of this enantiomer of trachelanthic acid and the first isolation of a retronecine ester from a *Heliotropium* species.

Structures of the two major alkaloids from *Crotalaria goreensis* have been confirmed by synthesis. *Crotalaria damarensis* contains 1-methylene pyrrolizidine, the major base present in *C. anagyroides*, while *C. dissitiflora* contains a new non-ester pyrrolizidine.

The structure of one of the alkaloids of *C. trifoliastrum* as 1-methoxymethyl-1,2-dehydropyrrolizidine has been confirmed by synthesis. A new collection of this plant contains as major alkaloid a base which has not been isolated from previous samples, and which constitutes yet another new non-ester pyrrolizidine. Variation of this kind is by no means uncommon and has also been observed this year with *Heliotropium supinum*, from which a large quantity of supinine has been obtained for biological testing and for synthetic purposes. A further large quantity of *H. europaeum* has been extracted to obtain stocks of lasiocarpine, heliotrine, and heleurine both for biological testing in the Division of Animal Health and to meet requests for pyrrolizidines from scientists in many parts of the world (*see* Chapter 8, Section 3).

Work was resumed on isolation of the toxic principle of *Atalaya hemiglauca*.

8. Root Exudates

The joint investigation with officers of the Division of Plant Industry of the possible ecological significance, in relation to the regeneration of *Araucaria cunninghami*, of *Backhousia angustifolia* leaf litter has been completed. Although *Backhousia* leaf oil constituents (angustione or dehydroangustione) inhibit germination under laboratory conditions, no such effect on germination of *Araucaria* in *Backhousia* leaf litter was demonstrated in the field. Evidence does not eliminate the possibility that germination of *Araucaria* may be inhibited in certain circumstances by *Backhousia angustifolia*, but these circumstances have not been defined.

Again in collaboration with officers of the Division of Plant Industry, the effect of root exudates on nodulation of subterranean clover has been investigated from the point of view of devising a suitable bioassay. The system employed throughout (growing subterranean clover in test tube agar culture) has been investigated thoroughly under conditions of controlled environment. Results show that the number of nodules is more profoundly affected by changes in the type of root medium and by the environmental conditions than by preplanting (i.e. by root exudates from plants grown previously in the same medium). Further biological work is necessary before it can be established that there is an organic chemical problem warranting investigation.

9. Sugar

Preparation of some sugar derivatives for possible non-food uses has been investigated. Investigations are only at an exploratory stage and have included examination of methods for preparing acetals. Among other derivatives 1-fluoro-α, D-glucose has been prepared and tested by the Wildlife Survey Section for toxicity to rabbits. It was found to be non-toxic.

10. Miscellaneous Investigations

Work continued on the oxidation of non-volatile aliphatic compounds at sites remote from the existing functional groups. A new method reducing di-aryl ketones to carbinols has been discovered. The rearrangement of unsaturated acids to γ-lactones and the pyrolysis of methyl ricinoleate have been explored. The existence of the thermal retro-aldol reaction has been confirmed, and its mechanism has been elucidated.

A gas chromatography unit has been designed and constructed with the needs of the organic chemist in mind. It incorporates both analytical ($\frac{1}{4}$ in. O.D.) and larger-scale preparative columns of various lengths (1 in. O.D.). The detector is a gas density meter, through which is passed about $1/30$ of the effluent of the larger columns. Attention has been given to the recovery and trapping of fractions.

35

Mineragraphic Investigations

1. General

The Mineragraphic Investigations section uses the highly specialized techniques of mineragraphic research to study in the laboratory the composition of Australian ore deposits. This work is done both as basic research, and also at the specific request of establishments concerned with mining production. The Section is located in the Geology Department of the University of Melbourne, and works in close collaboration with the C.S.I.R.O. Ore-dressing Laboratory which is also situated in the University (*see* Chapter 36). The Mineragraphic Investigations section provides research facilities which are complementary to those of the Ore-dressing Laboratories, and together these research establishments are able to provide the mining industry in Australia with very effective information on the composition of useful ore bodies, together with advice on methods for their full-scale treatment.

Work on utilization of minerals is carried out by the Division of Mineral Chemistry (*see* Chapter 31). Investigations by the Division of Coal Research on physical and chemical characteristics of Australian coals is recorded in Chapter 37. Work of the Chemical Engineering Section on utilization of brown coal is recorded in Chapter 33, Section 2.

A number of mining companies have continued through the Australasian Institute of Mining and Metallurgy to contribute towards the investigations of the Mineragraphic Investigations section.

No major change has been made in the research program. Twenty-eight investigations have been made of mineral associations in ores, rocks, drill cores, and mill products submitted by mining companies, and the Melbourne Ore-dressing Laboratory. In addition 13 papers have been published, and 5 papers are in press. Two new mineral species have been discovered — a natural nickel hydroxide, and a new copper telluride.

The first of a new series of C.S.I.R.O. Technical Papers, to be known as Mineragraphic Investigations Technical Papers, was published — "Roper River Oolitic Ironstone Formations".

Grateful acknowledgment is made of the cooperation of the University of Melbourne in providing laboratory accommodation and library facilities for the Section.

2. Investigations

Detailed study has been made of the difficult, fine-grained uranium ores from the South Alligator River area, N.T. In addition to massive and dispersed pitchblende, the primary ore contains minor amounts of several cobalt-nickel arsenides, arsenopyrite, pyrite, marcasite, chalcopyrite, galena, clausthalite, and galena-clausthalite solid solutions, a nickel selenide, and native gold. The uranium ochres of the oxidized ore revealed 26 secondary minerals, all finely intergrown. This report is the subject of a technical paper — No. 2 (in press).

A second major study completed during the year, part of the continuing program of research in the Broken Hill district, was concerned with "banded aplite" formations. These were shown to be most unusual rocks, the product of intense selective soda metasomatism along restricted rock horizons. The scale and intensity of the metasomatism renders the rocks unique, as far as known rocks are concerned, and evidence points to a post-metamorphic, magmatic source for the soda.

A study of drill cores from the Savage River magnetite deposit in Tasmania indicated that the sulphides in this ore represent a dispersed immiscible phase in the primary ore, and are likely to be present consistently in the unweathered ore.

Drill cores and underground specimens from the Orlando gold prospect, Tennant Creek, N.T., reveal an association of gold with chalcopyrite, bismuthinite, and brecciated magnetite rocks consistent with that found in the Peko mine, with some secondary sulphide enrichment at a depth of 380 ft. Gold ores and concentrates from the Bootlace Mine, Dargo, Vic., were studied and the occurrence of gold in concentrates from Mount Morgan, Qld., was investigated. Bismuth-rich ore from Broken Hill was found to have the bismuth in solid solution in galena.

The rare mineral bertrandite was found to be responsible for high beryllium assays in altered beryl from Mount Isa.

Bauxites from the Darling Ranges, W.A., were examined for their mineral composition.

Continuing collaborative work with officers of the Division of Plant Industry (*see* Chapter 3, Section 17 (i)) and of the School of Agriculture, University of Melbourne, revealed opal phytoliths (plant opal) and mineral particles in rumen contents of sheep, where they are a likely cause of wear of the papilli and the endothelial layer. They were also detected in lymph nodes of sheep. Examination of the uroliths ("calculi") that caused the death of a stud ram showed that silica was precipitated as opal in the pelvic portion of the uretha, giving rise to opal uroliths. Opal phytoliths and silicisponge spicules were embedded in the organic matter and amorphous silica constituting the uroliths. Authigenic "animal opal" was found also in phagocytes and macrophages in the lymph nodes of sheep.

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Ore-dressing Laboratories

1. General

C.S.I.R.O. has two Ore-dressing Laboratories. One of these is in Melbourne and is housed in the Mining Department of the University of Melbourne. The other is in Kalgoorlie, W.A., and is housed in the Kalgoorlie School of Mines. These two laboratories study the composition of ores and determine methods of ore-dressing for mining leaseholders, consultants, and others concerned with mining and metallurgy.

The Ore-dressing Laboratory in Melbourne provides a service to the mining industry which is complementary to that of the Mineragraphic Investigations section (*see* Chapter 35), and these two laboratories work in close collaboration.

Work on utilization of minerals is carried out by the Division of Mineral Chemistry (*see* Chapter 31).

2. Melbourne Laboratory

(1) *Administration.*—Cooperative investigations with mining companies continue to form a substantial part of the work of the laboratory. The project sponsored by Consolidated Zinc Pty. Ltd. on concentration of a Rum Jungle base metal ore will be terminated at the end of June 1960. A new project on the flotation of beryl is being sponsored during 1960–61 by Northwest Tantalum N.L. and Consolidated Zinc Pty. Ltd. jointly.

Officers of the Laboratory continue to provide advice and assistance to mining and other industries, by consultations in the laboratory and by visits to operating plants.

(2) *Investigations.*—The work of the Laboratory covered investigation of beach sands and of ores of gold, copper, nickel, uranium, silver, tin, and asbestos, and 24 reports were issued.

Work on beach sands from Western Australia and New South Wales related to recovery of by-product minerals and to special difficulties associated with recovery from particular deposits. A report has been issued on the application of classification and air tabling in the concentration of beach sand minerals.

In investigating the flotation of uraninite from northern Australian ores, special attention was paid to upgrading submarginal material.

Further investigation of a new treatment process for Wattle Gully Gold Mines N.L. gold ore culminated in the commissioning of a new plant at Chewton, Vic., by the Company in December 1959.

Progress was made in elucidating optimum conditions for gangue depression during concentration by flotation of base metals in an ore from the Rum Jungle district, N.T.

Success was achieved in floating beryl from a Western Australian pegmatite. For this ore it was possible to obtain reasonable grade and recovery figures by a less complicated process than that developed by the U.S. Bureau of Mines.

Work commenced on the beneficiation by flotation of low-grade limestone required for cement manufacture in Victoria. Preliminary results indicate that over 90% recovery of limestone with the concentrates containing over 90% $CaCO_3$ can be achieved.

Work commenced on investigation of the cyanidation process for extraction of gold from ores. Special attention is being paid to the treatment of gold-antimony ores at low alkalinities, and to the treatment of roasted auriferous sulphide concentrates containing lead.

Tests were completed on samples from two tin lode ores, three tin-bearing gravels, and a tin tailings dump. A satisfactory analytical method has been developed for the determination of tin in low grade samples. Concentrations of tin as low as 0.05% can be determined.

Other analytical work included an investigation of thorium in monazite, and other miscellaneous projects were preparation of dust samples to B.S.S. standard size distributions for testing air filters, and grindability tests to provide a better basis for future work.

3. Kalgoorlie Laboratory

Two reports of investigations were issued during the year. The first referred to ore samples from the Goodenough Gold Mine, Menzies, W.A., and the second to samples from the Hill 50 Gold Mine at Mt. Magnet.

Tests on samples from the Goodenough Mine indicated that a large portion of the gold occurred as tellurides, and explained the low gold recovery obtained by plate amalgamation at the Menzies State Battery.

Gold recovery tests on ore and final cyanidation residues from the Hill 50 Gold mine showed that gold not recovered by straking and amalgamation did not float readily in the presence of lime and cyanide. Screen sizing analyses of amalgamation residues indicated that the gold was not occurring as auriferous sulphide minerals. A large portion of the gold in the cyanidation residue samples was readily soluble in dilute cyanide solution.

Work is almost complete on gypsum and manganese samples submitted by the Government Geologist for beneficiation tests. It appears likely that products acceptable to industry can be prepared.

Throughout the year the senior research metallurgist was a member of the Chamber of Mines of Western Australia Committee of Metallurgists. This committee was formed late in 1958 and meets at 4-weekly intervals. The object of the committee is to discuss metallurgical problems and to coordinate test work. The Laboratory has cooperated with the mine laboratories in carrying out certain test work, and the senior research metallurgist continues as a member of the committee.

During the year 409 certificates were issued. These certificates record the results of assays and simple routine tests. The results are of interest only to the persons submitting the samples. This work has aborbed much of the time of the Laboratory staff, but a similar service is not available elsewhere in Western Australia.

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Division of Coal Research

1. General

The Division of Coal Research, North Ryde, N.S.W., is the principal establishment in C.S.I.R.O. undertaking research on fuels. The Division is engaged in studying and recording the physical and chemical characteristics of coals from all parts of the Commonwealth. Coal is a valuable natural asset, and Australia's major energy source. Reserves of the more valuable types of coal are limited, and adequate knowledge of their properties is essential if these are to be used to best advantage.

The Division of Coal Research is applying scientific techniques such as X-ray diffraction, mass spectrometry, ultraviolet and infrared spectroscopy, and vapour-phase chromatography to research on coal use, and also to the study of the constitution of coal to develop non-fuel uses such as the production of chemicals.

Work of the Chemical Engineering Section on utilization of brown coal is recorded in Chapter 33, Section 2. Work of the Cement and Refractories Section on brown coal ash is recorded in Chapter 32, Section 4. Work of the Organic Chemistry Section on brown coal tar is recorded in Chapter 34, Section 5.

There has been no major change in the research program of the Division of Coal Research, but the scope of the work continues to be restricted by limited resources of staff and equipment. This applies particularly to research on cleaning, combustion, and mechanical properties of Australian coals, and use and processing of coal tars.

The Division's fourth Symposium on "The Production, Properties, and Utilization of Foundry Coke" was held during the year. Those taking part included representatives of the coke manufacturers, the iron and steel industry, and the foundry industry, as well as officers of the Division.

As Australian representative on the Commonwealth Committee on Fuel Research, the Chief of the Division continues to act as coordinator of reviews of fuel research compiled by official fuel research organizations throughout the British Commonwealth on (*a*) physical testing of coal, and petrographic investigations; (*b*) brown coal, lignite, and peat. Officers of the Division act as special correspondents for reviews prepared in other Commonwealth countries on coal research.

During the year, over 30 reports of the Division's investigations were prepared and distributed, and many technical inquiries, mainly from industry, were answered. Three issues appeared of the Division's publication *Coal Research in C.S.I.R.O.*

2. Coal Utilization

(i) *Carbonization*

(1) *Improving Quality of Metallurgical Coke.*—Despite new technological developments coke, both as fuel and chemical reducing agent, is an important raw material in the ferrous and non-ferrous metallurgical industries. Research is being undertaken to improve the chemical and physical properties of cokes made from Australian coals, particularly those from the Northern Coalfield of New South Wales which have a high volatile-matter content. Methods have been devised to make better cokes by blending with these coals various carbonaceous materials, of which fluidized-bed char has proved the most satisfactory.

Coal from the Young Wallsend seam was blended with chars produced by the following procedures: fluidizing Wallarah coal in air at 500°C (char A), fluidizing Wallarah coal in recycle gas at 460°C (Char B), and fluidizing Young Wallsend coal in air at 500°C (Char C). Cokes produced from these blends were less fissured, were of larger size, but were of diminished hardness, compared with those from unblended coal. The optimum concentration of char was between 10 and 15%, and finely ground char (minus 72 B.S. mesh) gave better results than the coarser (minus 30 B.S. mesh) size. Chars A and C proved more satisfactory as blend components than Char B.

When up to 10% of inert material was blended with a high-volatile coal, the $1\frac{1}{2}$ in. shatter strength increased proportionally to the decrease in the volatile-matter content of the blend. Changes in the $\frac{1}{4}$ in. hardness were mainly due to changes in the bulk density of the blend expressed on an inert-free basis. Maximum coke hardness was attained when the additive was so finely divided that it packed tightly between the coal particles, leaving the minimum of free space into which coal particles could swell.

(2) *Production of Foundry Coke from Queensland Coals.*—Possibilities have been investigated of improving the quality of foundry coke from coal mined in the North Ipswich District of the West Moreton Coalfield. The coal tested was from the Haighmoor Extended Colliery (Fiery seam, presumed). Provided the following processing recommendations are implemented, this coal will give high-quality metallurgical coke:

> Any portion of the Fiery seam or any fraction of the colliery output may be used provided that its ash yield has been reduced below 12% (the only size fraction which could be washed satisfactorily was the minus $\frac{1}{4}$ in. plus 30 B.S. mesh coal from the upper split). The charge should have as high

a bulk density as possible, preferably above 53 lb/cu. ft., and should be as dry as possible (adverse effects of excess moisture can be reduced by adding small amounts of oil). It should be ground to secure a wide distribution of sizes below $\frac{1}{4}$ in. with a sufficiently high proportion of minus 72 B.S. mesh material, and carbonized at faster heating rates, or higher operating temperatures, than at present practised in local beehive ovens. To reduce fissuring of the coke, char, or coke, fines should be added to the charge, and improvement in the mechanical properties is possible by introducing lower-volatile coals into the blend.

(3) *Evaluation of Carbonizing Properties*.—Technical-scale carbonization tests were carried out on unblended New South Wales coking coals (Bulli seam, Valley Colliery) and gas-making coals (Greta seam, Bellbird and Pelton Collieries).

In technical-scale tests on coal blends, a high yield of rich gas as well as a hard, strong coke were obtained by carbonizing a blend of 60% Elermore coal (Young Wallsend seam) with 40% Pelton coal. In the commercial carbonization of blends of these two coals in gasworks retorts, a satisfactory compromise could be made between the high gas-making properties of the Greta and the fairly good coke-making properties of the Young Wallsend coal.

(4) *Mechanism of Coking*.—In further development of techniques for investigating the mechanism of coking, a method of "fractional thermogravimetric analysis" has been devised to determine not only the quantity but also the quality and composition of the volatile matter evolved. A tube containing the sample to be carbonized is suspended from the beam of a differential torsion-type thermobalance, and the volatile matter evolved is passed through various reagents before escaping to atmosphere. The continuously recorded decrease in weight is due to the loss of specific components of the volatile matter. Besides giving a record of the rates of evolution of tar, liquor, and gases from coal and similar compounds during pyrolysis, the method can be adapted to determine the amounts of carbon and of hydrogen evolved in volatile form, and the average density of the gases evolved during decomposition.

To study the chemical reactions involved when coal is carbonized, polynuclear quinones have been used as models. Examination of the chemical structure of semi-cokes derived from these model compounds called for investigation of methods of reducing quinones of high molecular weight to their parent polynuclear hydrocarbons. Reduction of the following quinones was achieved using *cyclo*hexyl-*p*-toluene sulphonate: dibenzanthrone, *iso*dibenzanthrone, pyranthrone, 4,10-dibromoanthanthrone, anthraquinone (and anthrone), 1,5-dimethoxyanthraquinone, and 1,8-dimethoxyanthraquinone.

(5) *Low-Temperature Carbonization*.—In the field of low-temperature carbonization, the high heat-transfer rates possible with fluidization and entrainment techniques have been investigated. The technical-scale plant in use for this work has a carbonizer unit 6 in. in diameter with a nominal capacity of 50 lb of coal per hour. The influence has been studied of such factors as carbonizing temperature, type of coal, fluidizing gas, and gas flow rates. The relative influence

of combustion and carbonization reactions upon the overall process depends upon bed temperature and mean particle residence time. Increase of carbonizing temperature within the range of 460–600°C gives a smaller yield of char and a bigger yield of liquid products. Maximum char yields at temperatures above 460°C were obtained by using the shortest residence times consistent with attainment of equilibrium. Maximum tar yields required longer residence times.

(ii) *Chemicals from Coal*

(1) *Chemistry of Coal.*—Coal is being studied as a raw material for chemical industry by subjecting it to progressive chemical degradation and thus obtaining evidence concerning the nature, number, and position of functional groups present and the arrangement of carbon atoms in the basic coal "skeleton".

Not all of the oxygen present in coals has been accounted for as hydroxyl, carboxyl, and carbonyl groups. New methods of estimating functional groups have therefore been devised, using (*a*) co-titration with 2,6-xylenol, (*b*) mesylation; these give higher values for acidic oxygen than older methods, with which it is difficult to estimate weak and hindered hydroxyl groups. This result suggests that more of the oxygen in coal may be in the form of hydroxyl than has hitherto been supposed.

A chemical and infrared spectroscopic study has been made of the products of treatment of brown coals with concentrated ethanolic or aqueous alkalis. The products (humic acids) contain aliphatically bound carboxylic acid groups, phenolic hydroxyl groups, and (where ethanol is the reaction solvent) alcoholic hydroxyl groups, reflecting a major redistribution of the oxygen-containing functional groups as compared with the original coal. Reaction paths involving decarboxylation, oxidative-hydrolytic fission of dihydric phenol structures, and subsequent hydrogenation via conversion of alkoxides into carboxylic acid salts, appear to be the most important steps in the formation of the coal hydrolysates.

Chemical studies showed similarities between brown coal and lignin. The similarity between the infrared spectrum of lignin treated with hydriodic acid and that of brown coal lends further support to the view that brown coal is essentially "demethylated dehydrated lignin".

These investigations gave rise to a possible explanation for the abnormal hydroxyl-group absorption which frequently occurs in the infrared spectra of non-hydroxylic compounds dispersed in potassium chloride disks.

Physical methods were used to determine the size, shape, and interaction of coal molecules in solution. No light-scattering could be detected even from dilute solutions of alkali-treated brown coals or of chemically reduced bituminous-coal extracts, owing to their powerful absorption. Diffusion measurements on an alcoholic solution of an alkali-treated brown coal indicated a weight-average molecular weight of 159,000; but sedimentation measurements with an ultracentrifuge showed that, excluding about 7% of "solubilized" material, the value was not greater than 16,000, and that for part of the solute it was 300–400. Viscosity determinations showed that the alkali-treated brown coal behaved as a polyelectrolyte in alcohol, and exhibited negative thixotropy.

(2) *Properties of Light Oils, Tars, and Pitches.*—Techniques such as molecular distillation, counter-current liquid-liquid extraction, and chromatography, as well as conventional methods of analysis, are being used in studies of the liquid by-products from low-temperature carbonization of coal in fluidized beds.

Investigations into the constitution, formation, and utilization of coal-tar pitch have been directed to improving the value of vertical-retort pitch as a binder for making anodes for the aluminium industry.

Of the processes investigated, two proved promising. The first, solvent extraction with ethanol, could become economic when operated in conjunction with processes for the removal of high-value tar acids from tar oils. The second is by heating the soft pitch at high temperatures in sealed containers.

(iii) *Combustion and Gasification*

(1) *Combustion Characteristics of Queensland Coals.*—Preliminary assessments have been made of coals from the Kianga and the Blair Athol coalfields.

Coal from the box-cut near Trial Shaft No. 3 on the Kianga field appears to have excellent burning and heating characteristics, but the ash yield is so low that there may be risk of overheating the grate links when the coal is burnt on chain-grate stokers. Further, unless care is exercised in combustion control, the relatively high phosphorus content of the coal (averaging 0.06%) may be conducive to formation of hard, phosphatic deposits on boiler heating surfaces. The coal may be less suited to firing on spreader stokers because of the slow build-up of the fuel bed, and the pronounced grit emission at high burning rates.

Combustion trials on coal from the Big seam, Blair Athol coalfield, showed that it would not be ideally suitable for burning on travelling-grate stokers. It would probably be unsuitable for a spreader stoker with travelling grate, but would give satisfactory performance in a dry-bottom, pulverized-fuel furnace. In view of the high silica ratio of the ash, without additives this coal would probably be unsuitable for slag-tap or cyclone furnaces. The sulphur, phosphorus, chlorine, and alkali contents are low and unlikely to cause serious corrosion or deposit troubles.

(2) *Aerodynamic Factors in Coke Beds.*—Studies directed to the more efficient use of coke in foundry cupolas have shown how to predict the pressure gradient in a coke bed from the air-flow rate, bed voidage, and coke particle size or shape. They have also thrown new light upon the relationship between the pressure drop through the bed and the percentage of fines present. The increase in pressure drop due to fines can be limited by charging the large and the small particles separately, in layers, provided that the layers of fine coke are at least three particles thick.

The "wall effect" in cupolas, which adversely affects their performance, was studied by model experiments. More than 40% of the total air flow escaped through the channels between the cupola wall and the adjacent coke particles. By applying a series of annular baffles to the wall the velocity distribution was improved and the wall flow reduced to 36% of the total. Better results were secured by interposing a layer of fine coke between the main coke charge and the wall. Air velocity in the centre of the bed was thereby greatly increased and the wall effect completely eliminated.

(3) *Chemical Reactivity of Cokes and Chars.*—Rates at which coke and other carbonaceous materials react with oxidizing gases such as carbon dioxide depend to some extent on their pore structure. A low-pressure ($\leqslant$ 1 atm) mercury porosimeter has been designed and constructed whereby measurements can be made of the size distribution of pores with entrances in the range 2,000,000–130,000 Å. With specimens of "Densite" metallurgical coke, and also with artificial graphite, pores were sufficiently wide for practically all the macropore volume to be filled with mercury at pressures less than 1 atm.

Another factor affecting rate of reaction of coke or char with carbon dioxide is the degree of penetration of the pore structure by the gas. This is largely determined by temperature; for example, penetration may be complete at 900°C but quite small above 1300°C.

3. Examination of Coal Seams

(i) *Seam Assessment*

In the systematic assessment of Australian coal resources, work carried out during the year was mainly on Queensland coals. Examination of three 4-in. bore cores from the Big seam, Blair Athol coalfield, showed the seam to be about 93 ft thick and to consist mainly of dull coal with isolated vitrain streaks and bands. There were occasional irregular bands and pockets of fusain and a few thin bands of shale, carbonaceous shale, and shaly coal. Thin veins of pyrite occurred throughout. The coal was bituminous, non-caking, low-rank (carbon content 82.5% on dry ash-free basis), and had a low overall ash yield (6.9–8.3%), high volatile-matter content (31.4% on dry ash-free basis), and low sulphur (0.17–0.36%), phosphorus (0.01%), and chlorine (0.01–0.06%) contents. A vitrinite-rich concentrate prepared from the seam had low caking properties (B.S. swelling number $1\frac{1}{2}$).

The petrographic composition of the seam was fairly uniform vertically and markedly so laterally. It comprised thick bands of durite and fusite with thinner and less numerous bands of intermediates, and only infrequent narrow bands of vitrite. Clarite was rare. The vitrinite was often contaminated with fine micrinite. The mineral-matter content was lower than the average values for other Queensland coals and for New South Wales coals.

Coal bands of high carbonate content, found in one of the bore cores, represented about 3% of the thickness of the seam and were the cause of a slight lowering of the ash-fusion temperature of coal from the whole seam.

In the West Moreton Coalfield, southern Queensland, profile samples were also examined in detail from the following collieries; Haighmoor Extended, and Rylance Abermain Nos. 1 and 2 (North Ipswich District), representing the Fiery (presumed), Eclipse, and Tantivy seams; also Box Flat Nos. 5 and 7 (Bundamba District), representing the Bluff and Wright seams.

In the Southern Coalfield of New South Wales a profile sample was taken of the Bulli seam at Wollondilly Colliery, and examined in detail.

(ii) *Inorganic (Mineral) Matter in Coal*

Inorganic (mineral) matter is found in all coals and contributes to such utilization problems as atmospheric pollution, troublesome slags and deposits in boilers and gas producers, erosion and slagging of refractories, and contamination of metals during blast-furnace or cupola operation.

Determinations made of the chemical composition and fusion characteristics of the ashes from most Australian coals indicate that ash composition is an unsatisfactory guide to fusion characteristics.

Methods developed for estimating total mineral-matter content (as distinct from ash yield) are being applied to New South Wales and Queensland coals. In view of the great importance of Victorian brown coals, special attention is being paid to the problem of determining the nature of their inorganic constituents.

Further progress had been made with the systematic study of the occurrence and abundance of trace elements in Australian coals.

(iii) *Petrography*

Petrological examination of coke structure proved valuable in planning carbonization tests and helped to provide standards of comparison of coke quality. Practical means were recommended for modifying the properties of cokes so as to render them more suitable for their intended fields of use.

In collaboration with the International Committee for Coal Petrology, further comparative analyses have been made to improve and standardize quantitative microlithotype and rank analyses in laboratories throughout the world.

Petrological studies have aided such varied investigations as examination of carbon anodes for the Australian Aluminium Commission, identification of crystalline phases in boiler deposits, and study of the structural changes in coke after reaction with carbon dioxide.

(iv) *Washability*

In the Northern Coalfield, N.S.W., the washability characteristics were determined of the Greta seam at Pelton Colliery, which consisted mainly of clean, bright coal. This coal (excluding the dirt bands) had a low ash yield (6.1%), a very high volatile-matter content (44.8% on dry ash-free basis), and medium caking properties (B.S. swelling number, 4½). All the size fractions from the run-of-mine coal had similar washability characteristics, so that there would be little advantage in separating a particular fraction for selective treatment. The ash yield of the run-of-mine coal was reduced from 9 to 7% by washing at a specific gravity of 1.60, the recovery of clean coal being 95%. Washing the coal did not, however, change its sulphur content or its phosphorus content (0.9 and 0.06% respectively, both on air-dried basis). Mineral matter remaining in the washed coal had a lower ash-fusion temperature than that in the rejects. In the Northern Coalfields, also, washability tests were made on samples from the Young Wallsend seam at Elermore Colliery. The upper portion of the seam at this colliery comprised interbanded coal and shale, and could not be washed satisfactorily in a gravity separation plant. The lower portion consisted mainly of bright coal with a very high volatile-matter content (38.8% on dry ash-free basis), and medium caking properties (B.S. swelling number, 5½). Including dirt bands, the lower portion had a very high ash yield (26.9%). It contained a 9½ in. band of mudstone, which disintegrated rapidly in water and would have to be removed to enable the coal to be washed satisfactorily. The ash yield of a bulk sample of coal from the lower portion was reduced from 29 to 12% by washing at 1.60 specific gravity, the recovery of clean coal being 75%. Washing did not alter the sulphur content or the phosphorus content appreciably (0.5 and 0.07% respectively, both on air-dried basis).

In the West Moreton Coalfield, the washability characteristics were examined of bulk coal samples from the upper and lower splits of the Fiery seam (presumed) at Highmoor Extended Colliery (North Ipswich District). The upper split consisted of friable coal, which, excluding dirt bands, had a medium ash yield (14.1%), a very high volatile-matter content (37.4% on dry ash-free basis), a low sulphur content (0.38%), and exceptionally high caking properties (B.S. swelling number, 8). Including dirt bands, the upper split had a very high ash yield (32.1%). Coal from the lower split was similar except that it had an even higher ash yield (19.6% excluding dirt bands and 36.2% including dirt bands).

Owing to the friable nature of the coal, and the relative hardness of the associated shale, the larger size fractions from both splits had markedly higher ash yields than the smaller. The washability characteristics of the plus ¼ in. fractions from the bulk sample of coal from the upper split were unfavourable in comparison with those of the minus ¼ in. plus 30 B.S. mesh coal. The latter comprised about one-third of the bulk sample.

For all size ranges, the bulk coal sample from the lower split proved to be less easily cleaned than the corresponding fraction from the upper.

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Physical Metallurgy Section

1. General

The Physical Metallurgy Section is a small group at the University of Melbourne Research School of Metallurgy, maintained by C.S.I.R.O. in cooperation with the University. The Section restricts its research to a few special problems in metallurgy; recently it has concentrated chiefly on the deformation of metals, although some work on titanium alloys has been continued.

Other C.S.I.R.O. groups undertaking research in various fields of primary or secondary metallurgy include: the Division of Tribophysics studying metal physics and the physics and chemistry of surfaces of solids (*see* Chapter 39); the Division of Mineral Chemistry studying the use of minerals and their derived products (*see* Chapter 31); the Division of Chemical Physics studying crystallography and solid state physics (*see* Chapter 29); the Mineragraphic Investigations section and the Ore-dressing Laboratories studying the composition and treatment of ores (*see* Chapters 35 and 36).

The research program of the Physical Metallurgy Section has continued without major change.

Staff of the Section have taken part in the supervision and guidance of post-graduate students in the Metallurgy Research School of the University. The Section has also answered many inquiries on metallurgical problems arising in industry and other Government Departments.

2. Titanium and its Alloys

A study was made of the relative deformation of alpha and beta phases in a duplex titanium alloy. It was shown that the alpha base is deformed less than the specimen as a whole, and it was concluded that the phenomenon of "beta embrittlement" is not due to the elimination of a phase in which the major part of the deformation of the specimen occurs.

3. Deformation

(1) *Slow Deformation in Relation to Creep.*—The work described previously has been continued by concentrating on one aspect of the mechanism of creep, namely, sliding at grain boundaries. A detailed analysis of previous work has been made, and a series of experiments commenced in which sliding will be measured at the surface and interior of specimens.

Measurements have been resumed of rates of grain growth in lead during annealing and of twin-boundary/grain-boundary energies.

(2) *X-Ray Microbeam Technique for Studying Creep.*—Initial experiments using X-ray microbeams have shown that fine-grained film is necessary for reliable determination of "particle" size and disorientation between particles. Such film is now being used, and the results obtained from lead specimens deformed by compression at room temperature indicate that both "particle" size and disorientation are linearly related to deformation, for deformations up to that producing recrystallization.

The investigation is being extended to the case of lead deformed at various rates in creep tests, with particular emphasis on the role of substructure in recrystallization.

4. Analytical Methods

Investigations on analytical methods conducted in conjunction with the Standards Association of Australia and the Commonwealth Tractor Testing Station were concluded prior to the departure on leave of the officer responsible for this part of the Section's work.

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Division of Tribophysics

1. General

Tribophysics means literally "rubbing physics" — that is, the physics of friction. The Division of Tribophysics had its origin as a group studying wartime problems of friction and lubrication. The original investigations of the Division have been extended to include fundamental studies in metal physics and the physics and chemistry of surfaces of solids.

Other C.S.I.R.O. groups undertaking research in various fields of primary or secondary metallurgy include: the Physical Metallurgy Section studying titanium and deformation of metals (*see* Chapter 38); the Division of Mineral Chemistry studying the use of minerals and mineral products (*see* Chapter 31); the Division of Chemical Physics studying crystallography and solid state physics (*see* Chapter 29); the Mineragraphic Investigations section and the Ore-dressing Laboratories studying the composition and treatment of ores (*see* Chapters 35 and 36).

The work of the Division of Tribophysics has continued along the general lines described in the Eleventh Annual Report. Cooperation with several University departments has again proved of great mutual benefit. Colloquia held with other metallurgical groups continue to be an important medium for the exchange of specialized knowledge.

Advice and assistance have been given frequently to numerous industrial firms, government organizations, departments of various universities, and other Divisions of C.S.I.R.O. The range of subjects — lubrication, bearings and bearing metals, wear, metals technology, electrolytic polishing, electronics, surface chemistry — illustrates the way in which the fundamental investigations of the Division are related to practical applications.

Many inquiries, especially those from some smaller firms, have shown that often insufficient use is made of technical knowledge freely available in the literature, an experience which is shared by the other laboratories in the C.S.I.R.O.–Department of Supply Engineering Group Committee. This situation can give rise to inefficiency and high costs in industry, and the Committee has prepared a report in which typical examples of inquiries are described and the benefits to be derived from greater use of technical control in industrial operations are indicated.

The research program on solid lubricants continues to be supported by H. C. Sleigh Ltd.

The new section of lubrication in industry and transport within the Institution of Automotive and Aeronautical Engineers has now been formed and a member of the Division is the chairman of the section. Officers of the Division continue to act on various other committees.

2. Properties of Surfaces

Apart from investigations on aspects of friction and lubrication, the Division's work on the physics and chemistry of solid surfaces is concerned mainly with processes for preparing surfaces (ion bombardment, and thermal polishing and etching), the nature of the surface after preparation, and the effect of these treatments on adsorption and catalysis. Most of the experiments have been carried out on large crystals to facilitate the interpretation of the results.

(i) *Friction and Lubrication*

(1) *Friction Drive Mechanisms.*—A number of experimental friction drive mechanisms have been constructed and the problems of hydrodynamic and boundary lubrication involved have been investigated. The results obtained have been promising and work is continuing.

(2) *Lubrication by Solid Lubricants.*—Investigation continued into the possible lubricating properties of several unusual substances derived from Australian minerals. Sulphides of titanium, zirconium, tantalum, niobium, and tungsten have so far been tested, but no outstanding frictional properties have been revealed. Tests on further substances are proceeding. The general mechanism of the adherence to surfaces of the conventional solid lubricants molybdenum disulphide and graphite is being investigated.

(ii) *Structure of Solid Surfaces*

An electron microscope has been installed during the year. Details of crystal surface structure can now be explored, using the microscope for observing the topography and electron diffraction techniques for detecting and identifying any contaminating films. Smooth surfaces are prepared by electropolishing followed by ion bombardment, whereas facets are produced by thermal etching. Condensation of gold on these surfaces discriminates between atomically smooth and rough facets, and shows which parts of the surface contain sites for nucleation. These will also be sites for strong adsorption.

(1) *Ion Bombardment.*—The erosion of metals by ion bombardment (sputtering) is being studied. An investigation of the effect of specimen temperature has been made, and it has been shown that the disorientation of the surface of the specimen by ion bombardment decreases as the specimen temperature is increased; also at a constant temperature the disorietation decreases with decreasing bombardment rate.

To obtain further information on the mechanism of sputtering a source of monoenergetic ions has been developed; this is a hot-cathode low-voltage arc, the plasma of which provides a copious source of ions with an energy spread of about $\frac{1}{2}$ eV. This source is being used to determine the sputtering thresholds for a number of metals and gases. Preliminary experiments with silver and argon have shown sputtering to occur at an ion energy of 20 eV, and at this energy a "deposit spot pattern" has been obtained from a silver single crystal.

(2) *Thermal Etching.*—It has been possible to explain the geometrical features of the fine ridges which appear on the surface of silver when it is "thermally etched", i.e. heated in air near its melting point for several hours, in terms of the differences in surface energy between different crystal planes. However, further experiments have shown that this explanation is not satisfactory since a thermally etched surface will become smooth if evaporation from the surface is prevented while it is being heated. Thus thermal etching is a kinetic phenomenon and a study is being made of the kinetics of evaporation from crystal surfaces of different orientation. A silver single crystalline ribbon when heated in air by an electric current will etch differently depending on the polarity of the current with respect to the surface orientation. This phenomenon, which indicates that a metal surface has charged atoms which can migrate upon it under the low electric field found in conductors, is being further investigated.

(iii) *Chemical Properties of Surfaces*

(1) *Monomolecular Layers on Water Surfaces.*—Earlier work in the Division on monolayers of stearic acid on very pure water demonstrated clearly that the behaviour on alkaline substrates, previously ascribed to ionization of the carboxyl group of the acid, is in fact caused by a reaction between the monolayers and impurities in the water. On very pure water ionization of stearic acid does not appreciably affect the molecular packing in the monolayer. This means that with stearic acid which has 16 methylene groups in the hydrocarbon chain, the lateral attraction between the chains outweighs that between the ionizable head groups. With molecules of shorter chain length it might be expected that a point should be reached where the contributions of head group and chain are comparable, and that ionization of the former will effect a change in the lateral packing of the molecules. Experiments carried out with acids containing 16, 15, 14, and 12 methylene groups showed that the contribution of the head groups becomes significant at 14 methylene groups.

(2) *Adsorption of Oxygen on Silver.*—Accurate, reproducible measurement of high temperature adsorption of oxygen on silver is of interest in connection with thermal etching and with catalytic oxidation, e.g. of H_2, CO, and C_2H_4. Results reported last year on silver powder prepared by filing and sieving were found to be incorrect due to carbon contamination, probably from the graphite mould in which the parent silver rod was grown. Numerous chemical methods of powder preparation are known to lead to contaminated specimens. Sintered silver films have been prepared by evaporation, and the apparatus has been redesigned to permit measurements to be made on the small surface area.

(3) *Catalysis on Single Crystals of Silver.*—A preliminary examination of the surfaces of the silver single crystals used in the formic acid catalysis has been made with the use of the electron microscope. Smooth planes appear to be present on the facets produced on the surfaces of crystals which have been thermally etched in air. The observation of the surface structure of the silver crystals should assist in interpreting the catalytic results.

The decomposition of hydrogen peroxide in the aqueous phase by silver crystals has been studied. Kinetics of the reaction are very dependent upon the cleanliness and roughness of the surface. Smooth, clean sputtered surfaces give first-order kinetics, while mechanically roughened surfaces give second-order kinetics and a more active surface. During the reaction a film of silver oxide is gradually produced on the surface, and the presence of this film decreases the rate of subsequent reaction.

(4) *Catalysis on Alloy Crystals.*—Some workers have related the activity of various metal catalysts to the geometric arrangement of the surface atoms. To investigate this, a copper-nickel-aluminium alloy (which undergoes a martensitic transformation at 250°C) has been used as a catalyst for the decomposition of formic acid. The martensitic transformation involves the rearrangement of the metal atoms and thus the catalytic activity before and after the transformation might be expected to be different. Preliminary experiments have shown the alloy to be a suitable catalyst, and sputtering can be used to clean the surface.

3. Metal Physics

The final aim of this work is to make possible the design of materials of specified properties and thereby widen the range of materials available to industry. To this end a better understanding must be obtained of the nature of strength and the mechanism of plastic deformation.

Strength and ductility depend critically on the imperfections in crystals. Most crystals contain various types of defects, particularly dislocations (displacements of atomic planes in a verner-like fashion), stacking faults (extended dislocations), and point defects (vacant lattice sites, impurity atoms, atoms in interstitial positions). To understand the origin of hardening occurring during plastic deformation, information must be available of the type, the number, and the arrangement of defects in plastically deformed crystals. To determine these three unknowns, measurements must be correlated of as many properties as possible made on the same material, and preferably on the same specimen. Properties determined in these investigations are internal energy, density, electrical resistivity, hardness, shape of X-ray diffraction lines, and shape and intensity of lines obtained in nuclear magnetic resonance.

(i) *Arrays of Dislocations*

The equations describing the mutual interaction of a group of dislocations are of a complicated type and cannot be solved mathematically except in special cases. A general method for solving such problems numerically by using an electronic computor was described earlier. This has been applied to more complicated problems involving the interaction of dislocations with surfaces and surface films.

(ii) *Lattice Defects and Order-Disorder Phenomena in Alpha Brass*

(1) *Annealed and Quenched Specimens.*—Studies of defects in alpha brass are valuable in solving the general problem of the role of defects in deformed, irradiated, or quenched pure metals.

A detailed investigation has been completed of the role of order and lattice defects in alpha brass. For slowly cooled alpha brass a marked absorption of energy occurs in the range 180–245°C on heating. If the specimen is first annealed at temperatures below 190°C, the amount of energy absorbed is markedly increased. A change in electrical resistivity accompanies this absorption of energy, and these results may be explained either by the destruction of long-range order with a critical temperature of 245°C or by the destruction of short-range order at a more rapid rate below 245°C than above.

Two different procedures are being used to distinguish between these possibilities. The first involves prolonged isothermal annealing treatments, and the second a study of the manner in which the ordering and disordering is affected by changing the composition, type of alloy, and the rate of heating.

The absorption of energy between 180 and 245°C in slowly cooled alpha brass is due to the destruction of order, whether long- or short-range order is involved. A state of much lower order than is present in slowly cooled specimens can be produced by quenching from high temperatures. The return of order in specimens quenched from 300 and 600°C on heating has been studied.

Specimens quenched from 600°C reorder rapidly below 160°C to a higher degree of order than that present in slowly cooled specimens. For specimens quenched from 300°C the intial degree of disorder is greater than reordering slower. The difference in behaviour between specimens quenched from 600 and 300°C is due to a higher concentration of quenched-in vacancies after quenching from 600°C. These excess vacancies anneal out between 160 and 245°C.

(2) *Deformed Specimens.*—The magnitude of the stored energy and the manner in which it is released from deformed alpha brass are very different from those observed previously for pure metals. Thus the energy stored in alpha brass is an order of magnitude greater than in copper for the same strain and is released in at least three stages as compared with one for pure copper.

The release of energy in the first two stages is large and is attributed mainly to the return of order destroyed by plastic deformation. Thus the first stage is probably due to rapid reordering assisted by vacancies created during deformation. The second stage represents the bulk of the reordering and some recovery involving rearrangement and annihilation of dislocations. Deformed specimens of alpha brass are strain-aged, and thus recovery is accompanied by the dispersal of atmospheres of zinc atoms, which increases resistivity and decreases density, to some extent counteracting the effects of recovery. The balance of these processes in the second stage of the energy release causes complex behaviour; the magnitude and even the sign of some changes in properties varies with the extent of deformation.

Reordering is complete before the beginning of the third stage in the release of energy caused by further recovery and recrystallization. Again the dispersal of atmospheres contributes to the changes in properties in this stage.

Comparison of measurements of energy, electrical resistivity, and density indicates that the high concentration of stacking faults generated by plastic deformation in alpha brass contributes to the changes in electrical resistivity on annealing. This supports the suggestion that such faults are a major source of scattering of electrons. Anneal hardening is observed after heavy plastic strain, and the maximum hardness coincides with the maximum degree of order. It is of interest that small plastic strains ($< 10\%$) order rather than disorder alpha brass.

(iii) *Point Defects*

(1) *Nickel.*—Measurements of stored energy, and changes in electrical resistivity and density accompanying annealing, have been made on nickel of 99.85% purity deformed in torsion and in compression. There are notable differences from the behaviour reported previously for nickel of 99.6% purity. The results show that, in the purer nickel, little or no recovery involving dislocations occurs between room temperature and the recrystallization temperature, in contrast to previous results for 99.6% pure nickel. There appear to be two stages of annealing prior to recrystallization in the 99.85% material, although they are not clearly resolved. These are centred at 120 and 260°C, and can be ascribed to the annealing of interstitials and vacancies respectively.

Stored energy measurements on still purer nickel of 99.96% purity deformed in compression show clear resolution of these first two stages, provided the deformation is low enough to ensure that recrystallization does not interfere with their observation.

(2) *Low Temperature Calorimetry.*—Instrumentation of the low temperature calorimeter, including the setting up of a new differential wattmeter, is complete, and testing of the apparatus has commenced. Preliminary tests indicate that the calorimeter will operate in the desired range of temperature from -180 to $+100$°C, and at the rates of heating required. Techniques which enable specimens to be set up in the calorimeter while immersed in liquid air have been developed.

(iv) *Structure of Deformed Metals*

Measurements have been made of the X-ray diffraction pattern of bulk specimens of nickel deformed by compression after annealing to various temperatures.

Analysis of the patterns suggests that on annealing to 600°C regions of high perfection are obtained in the nickel, and that the size of these regions is about 2–4 μ.

From Fourier analyses of the shape of the diffraction lines, values of the root-mean-square strain within the nickel grains have been determined. The energy stored in the lattice has been calculated from these strains and compared with the values of stored energy directly measured by using the calorimetric method. Reasonable agreement between the calculated and measured value of 0.28 cal/g is obtained if it is assumed that distribution of strain with the grains follows a Gaussian function.

(v) *Nuclear Magnetic Resonance*

Work on beta brass continued. Variation of intensity of resonance as a function of composition has been studied and this has enabled an estimate of the state of long range order in the alloy to be obtained. The effect of deformation and subsequent annealing has also been studied. Recovery of intensity of resonance indicates that considerable atomic rearrangement is taking place prior to recrystallization.

It has now been found possible to measure the broadening of the nuclear magnetic resonance line due to plastic deformation in copper. The increase in the mean-square width of the line has been shown to be proportional to the stored energy, and a theoretical interpretation has been given of this effect. Work on aluminium is proceeding along the same lines.

In conjunction with the Division of Textile Physics, an investigation has been made on the absorption of water by wool fibres. Using proton resonance, the intensity of resonance is a measure of the amount of water present, and the line width gives an indication as to whether the water is essentially "free" or bound to the fibres in some way.

40

National Standards Laboratories

Under the Commonwealth Weights and Measures (National Standards) Act 1948, the National Standards Laboratory, on behalf of C.S.I.R.O., is custodian of the legal standards of measurement of the Commonwealth. The National Standards Laboratory consists of the following Divisions:

The *Division of Metrology*, which maintains the Commonwealth standards of length and mass and their derivatives such as area, volume, density, and pressure (*see* Chapter 41).

The *Division of Physics*, which is responsible for the Commonwealth standards necessary for accurate measurements in heat and light, and which also maintains the basic electrical standards of resistance and voltage (*see* Chapter 42).

The *Division of Electrotechnology*, which maintains the Commonwealth standards of measurement of frequency (in conjunction with the Mt. Stromlo Observatory), and electrical standards derived from frequency, resistance, and electromotive force (*see* Chapter 43).

The Director of the National Standards Laboratory is Mr. N. A. Esserman. In addition to maintaining standards and providing a calibration service, the Laboratory engages in pure and applied physical research both to improve the basic standards of measurement and to assist in the solution of problems of importance to industry.

During the year the National Standards Commission met at the Laboratory and also met a Conference of Superintendents of State Departments of Weights and Measures.

Specialized help has been given to the Laboratory by the Division of Mathematical Statistics in providing a Principal Research Officer to assist in planning research and in analysis of experimental results.

Members of the staff have taken part in committees of national organizations and have given technical assistance to other Government Departments and to bodies such as the National Association of Testing Authorities.

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Division of Metrology

1. General

The Division of Metrology is one of the three Divisions of the National Standards Laboratory (*see* Chapter 40).

This Division maintains the Commonwealth standards of measurement of length and mass and their derivatives such as area, volume, density, and pressure. In addition to maintaining these standards, the Laboratory engages in pure and applied physical research, both to improve the basic metrology standards, and to assist industry with important problems in this field.

The work of the Division has followed the lines described in previous reports. Heavy demands are continuing on calibration and consultative services offered by the Division.

The machinability group of Applied Mechanics has moved to extended quarters in rented premises at Newtown.

At the next General Conference in October 1960, the International Bureau of Weights and Measures will consider adoption of the recommendation for optical definition of the metre. The main efforts of the Division have been directed to study of the problems involved in the change-over to this new primary standard of length. Equipment has been set up and extensively used for precision study of wavelengths emitted by krypton-86, mercury-198, and cadmium-114 isotope light sources.

2. Length and Associated Quantities

(i) *Standards*

(1) *Line Standards.*—The program of maintenance of the Laboratory's reference line standards was disrupted during the year by corrosion of two of the metre standards, one of 58% nickel steel and one of invar, whilst immersed in distilled water during a set of intercomparisons in the Line Standard Comparator. The basic cause of the corrosive attack appears to have been tricresyl phosphate released into the water from a length of plastic hose used in filling the tank. These line standards must be reconditioned or replaced.

Delivery of the platinum-iridium Prototype Metre No. 20 is not now expected until early 1961. Repolishing and regraduating of this Metre is taking longer than originally expected.

Construction and installation of an improved tank and temperature control system on the Line Standard Comparator (based on the work with an experimental tank reported previously) has reached an advanced stage.

Recalibration of the subdivisional scales of the micrometer microscopes of the Line Standard Comparator and recalibration of the resistance thermometers and of the Mueller Bridge have been completed during the year.

(2) *End Standards*.—Maintenance of the Division's reference and working end standards continued as usual.

(3) *Angle Standards*.—A further set of reference standards in the form of angle gauges has been acquired; these gauges have been calibrated at the National Physical Laboratory, England. Further calibration is being undertaken at this Laboratory and this will enable intercomparison to be made between the two Laboratories in regard to angle measurements of this type.

(4) *Surveying Tapes*.—Installation of the 4-metre line standard comparator has taken longer than originally expected, but is now proceeding satisfactorily, and the comparator will shortly be in operation.

A number of invar and steel tapes, ranging in length from 66 to 300 feet, have been calibrated on behalf of the Lands Department of several States, the Snowy Mountains Hydro-Electric Authority, and other authorities.

Assistance was given to the Department of the Interior (Lands and Survey Branch) in realigning the optical system of a geodimeter type NASM 4.

(ii) *Interferometry*

(1) *Wavelength Standards*.—A photoelectric recording Fabry-Pérot interferometer system has been set up and used extensively throughout the year for a precision study of wavelengths emitted by krypton-86, mercury-198, and cadmium-114 isotope light sources. Mechanical scanning is achieved by electromagnetic oscillation of the optical plates, and consequently, all wavelength measurements and spectral line profile studies can be done under vacuum conditions. The recording system for line profiles enables these to be recorded directly against change in path difference in a very simple manner. A special electrical controller and two-channel photoelectric recording head enable two wavelengths to be compared simultaneously. Vacuum wavelengths can thus be measured with very high accuracy, and small changes in wavelength of the order of a few parts in 10^9 are measurable. This equipment establishes with high quantitative accuracy the suitability of any light wavelength as an optical standard of length.

(2) *Light Sources*.—To develop a compact and convenient form of cadmium-114 lamp as a source of secondary optical standards, an electrodeless-type lamp of special design has been made. This promises to be a good practical light source for much work in metrology. Half intensity widths and wavelengths of the spectral lines emitted have been measured. A series of electrodeless-type mercury-198 lamps has been produced for general use.

(3) *Length Interferometry.*—The interferometer for establishing the 1-metre line standard in terms of the primary wavelength standard has been completed and is now being assembled. Dynamic measurements will be carried out as well as static measurements using electronic fringe counting techniques. Equipment for this purpose is under development. A photoelectric setting microscope has been designed and is now under construction for use with this interferometer. This equipment can be used to establish both end standards and line standards in terms of the primary light wave standard.

An interference comparator for comparing end standards up to 1 metre in the vertical position has been completed and used successfully. The comparator uses multiple beam fringes and is capable of measuring length differences of less than 0.002 μ, and is simple to use and adjust. A fully engineered model is now being designed.

A long-distance interferometer is under development for measuring distances up to 50 m by interferometry using optical multiplication processes. Design of the optical systems is completed and a major portion has been constructed.

The Kösters-N.S.L. interferometer has been used for calibration of the Division's end standards, and calibration and developmental work has been done on the accessory equipment for measuring temperature, and for measuring end standards under vacuum or precise temperature-controlled conditions.

(4) *Optical Phase Change Studies.*—The factor that is uniquely associated with length or wavelength measurement by interferometry is the phase change at reflection and is, in fact, one of the major sources of error.

Phase change at reflection from lapped steel surfaces is being investigated as a function of reflectance characteristics of the surfaces. A very sensitive electronic photometer has been made for measuring the ratio of diffuse to total reflectance at surfaces.

The phase change at reflection from high-reflecting multi-layer dielectric films and its variation with wavelength has been measured for a range of films used in interferometry.

Detailed study has been made of the classical interference relation and the form that it should take to account satisfactorily for physically known facts about phase change at reflection. The study has revealed confusion and conflicting results in the literature. A paper has been accepted for publication in which the literature is critically surveyed and the problem clarified.

(5) *General Interferometry.*—A mercury surface interferometer with a 6-in. field has been set up in which the effects of vibration and air turbulence on the mercury surface have been entirely eliminated. All master optical flats can now be tested with very high precision by multiple-beam interferometry, using the mercury surface as a naturally flat surface.

Interference microscopes in the Section have been calibrated for the effects of obliquity for objectives of different numerical apertures.

Long path difference interference experiments were undertaken in conjunction with the Division of Physics to demonstrate the use of the Fabry-Pérot interference filter to produce sharpened spectral lines giving direct interference in a Michelson system at path differences of 4–5 m.

New types of fixed invar etalons are under development to permit greater efficiency in the use of photoelectric recording and mechanical scanning methods of wavelength measurement. These will also be applied to further activities in both Fabry-Pérot and long-path difference interferometry.

A long-path difference Michelson interferometer is being designed for general research studies, including wavelength measurements, fringe visibilities, long-path difference interference, and refractometry and dispersion of gases.

Calibration of a $\frac{1}{8}$ Å Lyot-type filter was carried out for the Division of Physics using the photoelectric recording Fabry-Pérot interferometer described under wavelength standards.

(6) *Thin Films*.—An investigation of the adhesive properties of evaporated metal coatings on glass was completed. Antimony was particularly suitable in many cases for ruling through in preparing graticules by the double evaporation method. Graticules have been prepared successfully by this technique. Aluminium films of the required softness are also used for the first metal.

Equipment for controlling deposition of dielectric multi-layer films by photoelectric scanning methods is being constructed.

An improved mechanical Smith Chart has been constructed. This has been used to examine the optical properties of a number of multi-layer dielectric films and the effect of thickness variation has been investigated. A high-speed computing program has also been written for the SILLIAC computer, which gives very accurate evaluation of the optical characteristics of many-layered dielectric films.

A wide range of thin film coatings have been prepared for other Sections, Divisions, and outside organizations.

(iii) *Engineering Metrology*

(1) *General Measurement and Consultative Service*.—The Section continued to provide a calibration service to industrial and other organizations. This work ranges over the whole field of length and engineering metrology and includes the testing of machine tools, gauges, measuring equipment, components, and alignment of large structures. In addition, advice has been given on the setting-up of Standards rooms in industrial organizations, and on all types of measuring problems. As in previous years, this calibration and advisory service forms a substantial part of the Section's activities.

Work continued on examination of measuring equipment and reference standards of various types on behalf of the National Association of Testing Authorities, and also production and inspection gauging on behalf of the Department of Supply.

(2) *Gears and Gear Hobbing Equipment*.—A gear wheel hobbing machine, a spur and a double-helical test gear, and a number of large double-helical marine

gear wheels were examined on behalf of the Department of the Navy and the Department of Supply. In connexion with the test on the hobbing machine, a program for computation from numerical data of the mean cyclic errors of the various machine motions by an automatic computer has been designed and operated.

A number of other gears, including instrument gears, were examined on behalf of the Department of the Navy and also for industrial organizations.

To assist in the examination of tooth profiles, a set of master involute curves have been produced. These are in the form of line profiles on glass plates and are used in conjunction with a projector.

Advice on problems associated with the accuracy of gear drives has been given to other Divisions.

(3) *Air Gauging.*—A significant contribution to the techniques of air gauging has been the development, by an officer of the Section, of an extended-range air-gauging system. The basic feature of normal air-gauging techniques employing direct jets has been high magnifications (and accuracies) over fairly short measuring ranges of a few thousandths of an inch. The new device employs a moving jet which follows the surface contour, at the same time remaining a constant distance from it. The total movement of the jet, which can be measured by a wide variety of conventional measuring mechanisms, is largely a mechanical design problem rather than a pneumatic one; a prototype unit having a range of 0.1 in. and an accuracy of measurement within 0.001 in. has been constructed and operated.

The above development was instigated by a number of enquiries from industrial organizations manufacturing non-homogeneous material in sheet form (rubber, asbestos, cement, etc.) for a non-contact method of gauging having a relatively long range, reasonable accuracy, and fairly rapid response.

Preliminary investigational work has been undertaken on the discontinuities appearing in air gauging characteristics, which are attributable to transition from laminar to turbulent flow in the measuring jet.

The use of air gauging was continued for high-accuracy measurement of the internal diameter of a number of reference ring gauges and internal and external dimensions of special components. The latter include precision-bore barometer tubes and a silver-plated brass cylinder for a variable attenuator (for the Division of Electrotechnology).

(4) *Dividing Engines.*—Investigation (in collaboration with the Interferometry Section) to determine the best primary metal in the double evaporation process for production of scales on glass has shown that consistently good results can be obtained using antimony. Antimony will be used for this work over a fairly long period to obtain a sound assessment of its performance before deciding whether further investigation is necessary.

A number of scales of various types were produced during the year for use within the Laboratory, including a 1-metre stainless-steel line standard for the Interferometry Section, and a glass scale for use in calibration of aerial cameras.

(iv) *Electronics*

(1) *Fringe Counting.*—This apparatus is being developed as part of equipment for determining the length of a line standard in terms of the wavelength of light. This equipment has successfully undergone trials as a reversible counter using electrical impulses as a signal. It is at present being set up in conjunction with a Michelson interferometer, for experimental work using interference fringes.

(2) *Line Setting.*—An electronic unit is being developed for use in conjunction with a line scanning device developed by the Interferometry Section. It is hoped to obtain a setting accuracy of 0.01 μ.

(3) *Photoelectric Microscope.*—The electronic part of this equipment is ready for experimental trials with a suitable scanning unit. Experimental development has been carried out using an electronic circuit to simulate the optical system and vibrator unit.

(4) *Semi-automatic Gauging Equipment.*—This equipment is being developed in conjunction with the Applied Mechanics Section for measuring variations in the size and position of holes resulting from a repetitive drilling operation. These measurements can be made in two directions at right angles.

(5) *Transistor D.C. Amplifier.*—A D.C. amplifier, using transistors to avoid "noise" from the 50 cycle A.C. main, has been developed for measuring photomultiplier currents corresponding to low-intensity light sources. Results can be reproduced on the chart of a recording milliammeter.

3. Mass and Associated Quantities

(1) *Mass Standards.*—Installation has been completed of the 1 kilogram high-precision balance obtained for intercomparison of mass standards of the highest quality. The balance is located in one end of a basement room remote from the door. The room is divided by a partition between the balance and the door and, apart from the initial loading and poising, all weighing operations, including the addition of sensitivity weights and interchanging of the loads, are performed from outside the partition. Temperature conditions within the balance compartment have been found very steady when the door in the partition is closed.

Preliminary work with the balance shows that the sensitivity and reproducibility of rest point differences are such that a weighing accuracy better than 1 in 10^8 should ultimately be achieved. Internal consistency of weighings is also of this order. Results at present show unexplained jumps of the order of 6 parts in 10^8.

The Laboratory Imperial Standards of Mass were strengthened by the addition of two decimal grain sets of weights in non-magnetic stainless steel. In addition to these, a set of Imperial Standards 56 lb to 1 lb is approaching completion in the Laboratory.

A special set of poising weights comprising 11 pieces of value 2.0–3.0 mg in steps of 0.1 mg, have been added to the Laboratory metric standards.

(2) *Barometric Standard.*—The primary standard barometer mentioned in previous reports is approaching completion. The setting arrangements have been

modified, and use is being made of a pair of optical micrometers which have been constructed and calibrated. These enable setting to be made with microscopes on each mercury surface within a few microns. The scale of the barometer has been completed and the tube filled.

A comparison of the Laboratory working standard barometers with overseas standard barometers was made with the cooperation of the Division of Physics by utilizing the known calibration of a platinum resistance thermometer at the steam point and reading the pressure corresponding to a predetermined resistance value. Results indicate that the standard Fortin barometer departs by 0.03 mm Hg from the average pressure determined by some five standards in National Laboratories overseas.

(3) *Mass Measurement*.—Four of the balances used for maintenance of mass standards have been overhauled during the year and brought back to the required standard of performance.

A number of standard weights in both the metric and Imperial systems have been made in either stainless steel or aluminium bronze.

In view of the rapidly increasing use of balances utilizing mechanical loading of weights, a systematic examination was made of all weight-loading arrangements known to be used, and relevant equations for calibration of the weights *in situ* were developed.

In addition, requirements for the optimum arrangements in weight loading were formulated and details of several systems using different combinations of weights were worked out. It is of some interest that none of the commercial instruments so far examined use what is regarded as the optimum system.

A spot follower recorder was used to record the swings of a balance in the comparison of two standards of mass. Results agreed very closely with those obtained by visual recording of turning points but the computation from the record took considerably longer. Consideration may be given to this recording technique for recording results in the comparison of standards of highest grade.

(4) *Volume Measurement*.—An investigation was made into the calibration of micro pipettes used for measuring out samples of liquid for gas chromatography. Techniques were developed which enable pipettes of nominal capacity from 0.5 to 10 μl. to be calibrated with an accuracy of the order of 2%.

At the request of an industrial firm, methods are being developed for rapid examination of glass volumetric apparatus. Satisfactory techniques have been developed in the case of volumetric flasks and measuring cylinders, and work is continuing on apparatus delivering a specified volume such as burettes and pipettes.

(5) *Density Measurement*.—Substantial modifications have been made to the basic equipment for density measurements. The more important of these are the provision of means to interchange the load between the balance arms without removing the specimen from the immersion liquid, and the provision of means for vacuum immersion of solid specimens.

Minor changes include the provision of temperature control on the hydrometer calibration bath, and continuous water circulation round the measuring vessel during measurements.

Measurements of high precision were made of the density and dilatation of samples of commercial styrene and of samples of commercial benzol (C_6H_6) in the dry state and saturated with water. Similar measurements were made on specially purified benzol in which the residual impurities were measured by gas chromatography.

(6) *Pressure Measurement.*—The pressure controller mentioned in a previous report, whilst giving adequate control, has proved difficult to operate satisfactorily, largely on account of mechanical inertia in the proportioning valve. To improve the operating conditions, the proportioning valve has been replaced by a pair of magnetically operated control valves operated by thyratron relays which are actuated by the output from the phase sensitive detector.

(7) *Photogrammetry.*—Demands for calibration of various types of aerial cameras are increasing, and investigational work in this field has largely been directed to improvement of test methods and facilities.

The problem of distortion introduced by camera windows in aircraft has been examined at the request of the National Mapping Council. It has been suggested that a satisfactory solution to this problem would be the use of a spherical window of constant thickness in which the centres of the two spherical surfaces are at the centre of the entrance pupil of the lens.

(8) *Lapping and Abrasives.*—In connexion with the apparatus mentioned in a previous report for sharpening hypodermic needles, an instrument has been developed for comparing sharpness of needles. The instrument measures the force required for the needle to penetrate a standard material when presented to it at a predetermined rate, and has yielded information on how various parameters affect the ability of a point to penetrate a standard material.

Development was completed of an apparatus for feeding on to a lapping plate a fine abrasive powder suspended in a liquid. The rate of flow obtainable with the apparatus may be varied from about 12 to 1500 ml per hour. It has proved quite reliable in operation and is completely free from trouble due to clogging.

Manufacture of slip gauges for special purposes and finishing of special components has continued, and assistance in the lapping of components has been given to other Divisions.

(9) *Calibration and Consultative Services.*—There has been a slight falling off in the number of sets of weights submitted for test, but in other fields the demand was slightly increased. Inquiries for advice and assistance continue at much the same level as in previous years.

4. Applied Mechanics

(i) *Measurement of Physical Quantities*

(1) *Force.*—Seven new proving rings, ordered during the previous year, have now been received. Two of these are of the conventional Morehouse design with capacities of 2000 and 56,000 lb. The remainder are of the self-indicating type, being fitted with dial indicators, and have capacities of 30, 150, 500, 1000, and 10,000 kg. A 5000 lb proving ring of the conventional type has been ordered.

Attention has been given to problems associated with the provisions of primary standards of force which are essential for the calibration of existing proving devices and for the development of new ones. Lack of suitable accommodation within the Division has, however, prevented positive action being taken.

(2) *Pressure*.—A 5000 lb per sq. in. dead-load pressure-gauge tester having an accuracy of ± 0.03% has been purchased.

(3) *Hardness*.—The dead-load diamond pyramid hardness testing machine 0.2–10 kg, ordered during the previous year, has been received and is being set up.

Use of the 30 and 150 kg self-indicating type proving rings has facilitated measurement of the indenter loads of Rockwell hardness testing machines with a consequent reduction in the time taken for the calibration of these machines.

(4) *Angular Speed*.—A note has been submitted for publication describing an extrapolation technique for measuring angular speed using a stroboscope and a multi-point pattern instead of the single-point one normally used with the technique.

(ii) *Vibration*

(1) *Vibration Isolation*.—The main activity this year has been theoretical study of large seismic mountings. The principle is well known of isolating equipment, assumed to be rigid, from continuous (steady-state) vibration of the support or site. In actual installations such ideal conditions are rarely met: the equipment is not rigid; the vibration pattern may be a changing one, of non-uniform magnitude and mixed frequencies, punctuated with transient effects; the isolators may not have constant stiffness; the mounting has six natural frequencies, not necessarily independent; and the support may vibrate in a number of modes. The group has made an attack on this complex problem by treating the machine tool on the seismic mounting as an equivalent two-mass system and has derived an exact analytical solution, using Laplace transforms, for the relative motion between the second mass (the flexible element of the equipment) and the first mass (the machine frame plus block) resulting from a damped harmonic vibration of the support.

This has involved assumptions of linear stiffness, ideal viscous damping, negligible reaction of the flexible element on the main mass, and a vertical mode of vibration. Work has been extended to give a more detailed study in the resonance zone where the site frequency, the natural frequency of the mounting, and that of the cutting element are close together. A paper covering the foregoing has been prepared and accepted for publication. Further consideration has been given to extending the analysis to take account of the reaction of the second mass on the first.

It is not always possible to arrange the isolators in actual mountings in a symmetrical way which facilitates the computation of the natural frequencies. A paper has been prepared and submitted for publication showing how the natural frequencies can be computed with little difficulty for a mounting on any layout of identical isolators, symmetrical or otherwise, in which the isolators are equally loaded and in a common horizontal plane. A further note is being prepared for publication proposing an extension of the method to mountings in which the isolators are not in the same horizontal plane. Some consideration has also been given to the influence of non-linearity of the isolators.

(2) *Vibration Measurement*.—Further work has been done on the development and calibration of a small capacity-type accelerometer. Preparations are being made for the calibration of vibration transducers using interferometry techniques developed some years ago in the Division.

(3) *Dynamic Balancing*.—A short note has been prepared for publication on the calibration of compensating-type dynamic balancing machines.

(4) *General*.—Service on vibration measurement and isolation problems was given to industrial and other organizations when the work could not be diverted to vibration consultants. These related to site and structural vibrations; testing of a prototype spring isolator; vibration of a long cutter-roll; dynamic balancing *in situ*; calibration of a portable vibration meter; testing of vibration isolating materials; vibration isolation of chemical balances, optical instruments, precision machine tools, and gas compressors.

A lecture on the response of non-rigid equipment to a transient vibration of the support was given by an officer of the Section at a seminar at the Sydney University Mechanical Engineering Department.

(iii) *Engineering Design Analysis*

(1) *Design Techniques*.—A paper was published on the application of probability to the tolerancing of machined dimensions showing the techniques specially developed at the Laboratory for engineers and designers.

The techniques were applied in analysis of the end-play requirements for a small electric motor to be manufactured by a local firm to overseas drawings and specifications. Study revealed that it was impossible to meet the end-play specification with the dimensions and tolerances as specified on the drawings. An analysis was then conducted to determine how the dimensions and tolerances should be modified to meet the specification. In this particular case, the analysis was carried right through to the final inspection and the practicability of the inspection fixture designed and recommended by the Laboratory was demonstrated.

The Section cooperated with the University of Queensland in a series of special lectures entitled "Dimensioning of Engineering Drawings" arranged for Queensland engineers by the Mechanical Engineering Department. The series of problems on "Geometric Analysis of Engineering Designs" used in the Summer Schools last year was made available by the Laboratory for use in this course of lectures. This series is now being prepared for publication.

A series of data sheets on geometric analysis is being prepared for publication. These will help designers, draughtsmen, production engineers, and others interested, to appreciate the usefulness of geometric tolerancing and give them an understanding of the principles underlying the methods of dimensioning and tolerancing of Section Two of BS.308:1953 Engineering Drawing Practice.

(2) *Measurement.*—Measurement of the hook, rake, and relief angles of screwing taps requires the setting of a graticule cross-line so that it is tangential to a circle. Instruments on the market claiming to measure these angles do not provide means for positive location of the tangent. A note is being prepared for publication showing the method developed at the Laboratory to achieve this.

(3) *Process Variability.*—Study of the process variability of typical machining operations has continued throughout the year and has included tapping, turning, and drilling. A paper on the effect of nut-blank dimensions in automatic nut tapping has been published and two further papers prepared for publication, one dealing with the effect of tap relief in nut tapping and the other with recommended techniques for dimensional analysis of production processes. Results of an investigation on process variability of an automatic screw machine are being programmed for analysis by computer.

A study is being made of the influence of drill geometry upon the variability in position and size of a jig-drilled hole. To facilitate measurement of components and analysis of results, a measuring unit has been developed to measure automatically the size and position of the drilled hole and record each dimension, in turn, on a punched card. These cards will then be processed through a computer to give with minimum delay the parameters required to assess process variability.

The effect of changes in the material structure upon the dimensions of components machine in turning, drilling, and tapping operations has been studied. Comparisons have also been made between leaded and non-leaded free machining steels.

(4) *General.*—Assistance was given to a local firm in the preparation of data sheets for gauges, including recommendations on dimensioning and tolerancing.

Following a request from a Government factory, a subassembly was analysed and drawings prepared to illustrate the application of the principles of geometric analysis. Assistance was also given to a State Department in the measurement of tool geometry for timber drilling tests.

(iv) *Machining Research*

(1) *Machinability of Australian Materials.*—Collaboration with the Broken Hill Proprietary Co. Ltd. has continued throughout the year, particularly on the machinability of free-machining steels, and good progress has resulted. Further experience with the quick-facing test has confirmed its utility in assessing the machining characteristics of the billets, and this test is now being used to relate the machining properties of free machining steels to their chemical composition. Experiments are proceeding and the results will be analysed using a digital computer. The outstanding results of work on the free-machining steels have been the disclosures firstly, that this type of steel is "speed-prone", i.e. relatively small changes in cutting speed lead to large changes in tool life; and secondly, that carbon content has a significant effect upon tool life — the larger the carbon content, the shorter the tool life. The variability range in tool life with this type of steel is therefore quite wide. Once the effect of chemical composition is fully

understood, it may be possible to help the steelmaker produce a better product from the point of view of machinability, by balancing the composition of individual heats.

The facing test is not suitable for small diameter bars, and work is proceeding on the development of parting and turning tests for this purpose. The work has been done on both aluminium alloys and cold-drawn free machining steel, and first results show some promise.

(2) *Cutting Tools.*—Full-scale tests are being conducted on several makes of ceramic cutting tools obtained from widely separated sources throughout the world. Early results have shown that some of these ceramics have improved shock resistance qualities. A paper has been accepted for publication overseas, describing the formation of a smeared layer of work material on the flank of a ceramic tool.

(3) *Basic Research in Machining.*—A thermal analysis of the shear zone in metal cutting has been carried out which for the first time deals quantitatively with the geometry and temperature distribution in the fan-shaped deformation region just ahead of the cutting "edge".

The quick-stop tool dynamometer for "freezing" the cutting action has undergone successful tests. Experimental work with this equipment is being carried out in conjunction with a new approach to metal flow past a blunt cutting edge. The nature of metal flow past such an edge may well prove fruitful since no cutting edge is perfectly sharp.

(4) *General.*—An improved three-dimensional cutting tool dynamometer has been designed for use on centre lathes.

One research lathe was converted to continuously variable speed control, the spindle speed was doubled, and the power increased by 50%. Another research lathe was modified to operate from the standard voltage so that the power supplies could be interchanged.

42

Division of Physics

1. General

The Division of Physics is one of the three Divisions of the National Standards Laboratory (*see* Chapter 40). This Division is responsible for maintaining the Commonwealth standards of measurement in heat (the International Temperature Scale), light, hygrometry, and viscometry. The Division has established facilities for a wide range of precision measurement and calibration in these fields, and it provides advisory and consultative services for industry and other laboratories. The Division undertakes special investigations on applied projects of importance to industry, and also conducts basic research programs in solid state and solar physics.

During the past 12 months the total number of reports, certificates, and statements of examination issued by the Division has risen sharply to 501. Nevertheless, it is pleasing to note for the first time a falling off in certain aspects of industrial testing due to steady improvement in the technical facilities of industry for such work. More time is consequently becoming available for concentration on special problems, standards development, and research.

Close association with the National Association of Testing Authorities, particularly in the field of heat and temperature measurement, has resulted in general improvements both in standards and equipment among registered laboratories. The Division's policy of assistance to industry in the training of technical personnel is also proving effective in this regard. Total attendance at regular pyrometry schools has now passed the 200 mark, while individual training has been provided in other fields as required.

2. Measurement and Control of Temperature

(i) *International Temperature Scale*

One of the Division's main responsibilities is the maintenance of the International Temperature Scale (I.T.S.). Adopted by the 9th General Conference on Weights and Measures to provide a uniform means of measuring temperatures throughout the world, it conforms as closely as practical to the thermodynamic scale. The I.T.S. is modified from time to time when new knowledge justifies such action or there is need for definition of a new range of temperature. Several major alterations currently under consideration have a bearing on the work of the Laboratory.

As a whole, the Scale may be divided broadly into three parts. From the boiling point of oxygen (−182.970°C) to the freezing point of antimony (630.5°C), temperatures are measured with a platinum resistance thermometer. From the freezing point of antimony to the freezing point of gold (1063.0°C), temperatures are measured with a thermocouple of platinum and platinum-rhodium. Above the gold point, the temperature is defined by reference to Planck's Law.

Recent developments relating to the maintenance of the I.T.S. are described below.

(ii) *Resistance Thermometry*

One recommendation of the Comité Consultatif de Thermométrie in 1958 was the use of the freezing point of zinc (419.505°C) in preference to the less reproducible boiling point of sulphur (444.600°C). Although fundamentally more satisfactory, the zinc point is very sensitive to impurities, and it has been found necessary to adopt zone refining techniques to obtain satisfactory material; quite large amounts of impurity have been found in nominally pure zinc. Other melting points, for example those of cadmium and tin, are also being studied as possible replacements for the present steam point or as intermediate check points on the I.T.S.

Tests are being carried out on the stability of the cells used for realizing the triple point of water. Intercomparison of cells made in 1953 with others made during the past year by a quite different method showed no differences as great as 0.0001°C.

One of the main problems in establishing boiling points is the accurate realization of the standard pressure. Preliminary tests with a capacitance probe mercury manometer of new design indicate that it is possible to locate the mercury surfaces to much better than 0.1 μ, and this will result in a substantial improvement in the Laboratory's accuracy of realization of boiling points.

It would be desirable to be able to extend the upper limits of the useful range of platinum resistance thermometers, not only for replacing thermocouples to record temperatures up to the melting point of gold, but also to improve thermometer stability at their present upper limits of usefulness. Investigations are being made on the suitability of various materials and mountings for these thermometers.

(iii) *Thermocouple Pyrometry*

In the range 630–1063°C, accuracy depends largely on the freedom of platinum, platinum-rhodium thermocouples from physical and chemical impurities. As the liability to contamination increases markedly at high temperatures, and in any case the upper limit of these thermocouples is the melting point of the platinum wire, investigations are being conducted on thermocouples made with more refractory metals such as tantalum and niobium, which can now be obtained with a very high degree of purity. A tantalum tube furnace designed to give the high temperatures and uniformity required is at present being tested for operation up to 1800°C.

(iv) *Optical Pyrometry*

Above the melting point of gold (1063°C), the I.T.S. is translated into practice by means of optical pyrometry. Investigations over the past two or three years have doubled the accuracy obtainable, though the ultimate accuracy of the conventional visual optical pyrometer is unlikely to exceed ± 2°C (at the 99% confidence level) at the gold point. Increasing demand for higher accuracies has directed attention towards photocell techniques, and a photocell disappearing filament optical pyrometer recently developed has been used as a transfer device with an accuracy of ± 0.05° at 1100°C. This sensitivity is sufficiently great for investigating the stability and temperature uniformity of the tungsten strip lamps used as brightness sources in calibrations. Enough information has already been obtained to indicate that a new design of lamp is required, and a number of experimental lamps are being made for such purposes.

(v) *Temperature Scale in the Range* 0–4°*K*

Quite generally, the accuracy of temperature measurements has limited the usefulness of measurements of physical properties of materials in the range below 4°K. As a consequence of the adoption by the Comité International des Poids et Mesures (1958) of a new helium vapour pressure scale of temperature for this region, work is in progress which it is hoped will lead to its realization with an accuracy of about 0.0001°C.

(vi) *Temperature Scale in the Range* 20–90°*K*

Effects of impurities in the platinum of resistance thermometers used in this range have been investigated, and it has been shown that, with suitable thermometers, it should be possible to interpolate temperatures to a reproducibility of better than 0.01°C.

(vii) *Assistance to Industry*

There has been continued demand for the calibration of high-grade mercury-in-glass thermometers, thermocouples, optical pyrometers, and other temperature measuring equipment; over 350 mercury-in-glass thermometers have been calibrated during the year. In many cases it has been necessary for calibrations on industrial installations to be made *in situ* because the establishment concerned has had neither the necessary equipment nor the trained personnel for the purpose. To help overcome the personnel deficiency, the Division has held schools in temperature measurement from time to time, the most recent, in March 1960, attracting interstate visitors from as far afield as Western Australia. Their cumulative effect is now being felt, and has resulted in an appreciable falling off of routine furnace testing, enabling more time to be spent on special problems.

One problem important in a range of industries is the measurement of surface temperature, and investigations have been made, for example, on surface temperatures of plastic moulds and temperatures reached by aluminium strip during enamelling. Typical of other special problems has been the measurement of temperatures inside bones during the healing of bone fractures. Methods have also been developed for measuring pH in the latter project.

Investigations are also being made on the properties of copper-wound resistance thermometers of various types. Methods have been developed for constructing such thermometers with up to 300 turns of bare enamelled wire per inch on an insulated metal former. This work is being extended to coils of silver and gold wire, since the technique combines the advantages of a practically strain-free winding and a very high heat transfer coefficient between wire and former.

The Division has been closely associated with the investigation of laboratories applying for registration with the National Association of Testing Authorities. In all, 20 industrial laboratories have been considered for registration for heat and temperature measurements during the past year. This has involved inspection of each laboratory's equipment, housing, and personnel, and the calibration of its relevant standards of measurement. There is good evidence that this service has improved the general level of testing in these laboratories, with considerable benefit to the industries concerned.

The association with N.A.T.A. registration has revealed an all too common need for adequate furnaces and baths for calibrating thermometers and thermocouples. To meet such demand, a thermometer calibrating bath and a thermocouple checking furnace have been designed for cheap construction from readily available materials.

(viii) *Cryogenics*

In the cryogenics field, service rendered to other laboratories has included guidance on the design of a small liquid hydrogen plant, and assistance to the School of Public Health and Tropical Medicine in the University of Sydney in the storage of living tissue in liquid air. Assistance has also been rendered to other Departments in the Universities of Sydney and of New South Wales in connexion with low temperature research problems.

3. Solid State Physics

The solid state physics program is designed for the study of the physical properties of both metallic and insulating substances, and the interatomic forces which determine these properties. Observation of thermal and electrical conductivities of solids down to very low temperatures continued to be a valuable source of information, as have studies of paramagnetic resonance absorption. Information is also being obtained now on thermal expansion at temperatures lower than heretofore and on specific heats.

(i) *Transport Phenomena*

In continuation of the work on conduction of heat by thermal vibrations of the crystal lattice, a study has been made of scattering of these waves by foreign atoms of mass very different from those in the parent lattice. Measurements are nearing completion on alloys of platinum in copper (as parent metal), aluminium in silver, etc., in which there is fairly good agreement with a "simple" scattering theory (due to Klemens), taking only mass difference into account. It does appear that lattice distortion also makes some contribution to the scattering in copper-silicon alloys.

The effects of cold rolling and annealing on low temperature conduction properties have been investigated in a copper-antimony alloy. In general, the resistances of pure metals and of most alloys decrease on annealing owing to removal of lattice defects. Recent reports that an unexpected increase, rather than decrease, in resistance occurs on annealing have been confirmed, but resistance does not change appreciably on later re-rolling. The observations, including metallographic examination, suggest that this increase may be caused by an initial lack of homogeneity rather than the hypothetical segregation of solute atoms (due to migration) during the cold work stage.

Some recent overseas measurements of the Wiedemann-Franz-Lorenz ratio (ratio of thermal to electrical conductivity) on very pure copper cast doubt on previous conclusions, obtained both experimentally and theoretically, that the Lorenz number should approach its theoretical Sommerfeld value at the lowest temperatures. However, a further experimental study on very high purity copper has confirmed the earlier conclusions.

(ii) *Thermal Expansion and Specific Heat*

Application of techniques of accurate capacitance measurements (developed by the Division of Electrotechnology) to measuring linear expansion coefficients has already proved fruitful. The present sensitivity or detection limit of about 1 Å has made it possible to extend the existing expansion data on copper from 25°K down to 6 or 7°K. It appears from these data that any electronic contribution to thermal expansion in copper is probably rather smaller than expected, but further measurements are required between 1 and 5°K, using proposed improvements in sensitivity, before this can be certain. Thus far, these observations on length changes in copper below 25°K have been made relative to beryllium (a substance whose dimensions should be constant at these temperatures). Another expansion cell is being completed for absolute measurements on copper, and measurements are also planned on iron, lead, and aluminium relative to copper.

Measurements of the expansion of pure chromium (nitrogen-free ductile chromium from the Aeronautical Research Laboratories, Melbourne) have shown that an anomalous "bump" near 38°C persists in this high purity material and is presumably an intrinsic property associated with the onset of antiferromagnetism.

Problems of building vibration have affected the specific heat program and have necessitated the improved isolation of the specific heat equipment. Improvements are also being made to the method of extracting heat from the test specimen, as a result of which operation to somewhat lower temperatures can be expected in the near future.

(iii) *Paramagnetic Resonance: Maser*

The Division's available techniques have been increased by construction of a "zero-field spectrometer". In normal paramagnetic resonance studies the frequency of the incident microwave radiation is kept constant, and values of an applied steady magentic field are sought at which the test substance absorbs the microwave radiation. From this an expression for a "spin-Hamiltonian" can be constructed which should predict the behaviour of the energy levels of the paramagnetic ion in its crystalline environment as a function of applied field. Only one substance, viz. gadolinium ethyl sulphate, has ever been subjected to experimental study at zero magnetic field, when appreciable discrepancy was found between theory and experiment. The present zero-field spectrometer, believed to be the first of its type, enables resonance measurements to be made by varying the frequency throughout the range 12.4–18 kMc/s. The substance at present being investigated is aluminium acetyl acetonate containing a small proportion of iron, which is the paramagnetically active agent. Ordinary paramagnetic resonance experiments have previously shown that this material should be extremely suitable as the working substance of a "zero-field maser", and preliminary measurements with the new spectrometer tend to confirm that the frequencies concerned are indeed very suitable, lying in the well-known radar X-band.

Ordinary paramagnetic resonance work has been facilitated, and the sensitivity of the equipment increased, by the construction of a frequency-controlling apparatus and a 100 kc/s magnetic field modulator. Work on the presence of free radicals in irradiated materials has been carried out in cooperation with the Department of Chemistry, University of New South Wales, and with the Wool Research Laboratories and the Division of Coal Research.

Maser development as such has rested largely in the hands of the Division of Radiophysics, who have made a packaged version of the ruby master (originally jointly developed by the Divisions of Radiophysics and of Physics) to be used in conjunction with their Potts Hill installation.

4. Hygrometry

Facilities are maintained for providing calibration and advisory services in hygrometry, a field of continually growing interest. Assistance has been provided on such industrial problems as measuring the water content of the atmosphere in a baking oven (where conditions are such that the dew-point substantially exceeds the ambient temperature), and the rapid measurement of dew-points in the neighbourhood of −50°C at pressures substantially below atmospheric.

A number of hydrometric instruments have been under development during the last few years. One of the principal of these is the electrolytic condensation hygrometer, a precise and rapidly responding instrument which utilizes single crystals of various salts; this is now in the prototype stage of commercial production. There have also been further developments in the probe hygrometer, an instrument incorporating electrical humidity-sensitive elements of the anodized aluminium type, the procedure for making which has been completely revised and improved during the past 12 months. It should not be long before these elements, together with a portable unit for calibrating them, are available commercially. Because of its rapid response, portability, and smallness of size, this instrument promises to be of wide application, and it has already received considerable trial by interested laboratories.

A third instrument developed has been a condensation hygrometer with a temperature-controlled condensing surface; recently completed, this has now been brought into service for testing purposes, and has proved of special value for measurements made on industrial installations.

To find substances more versatile than potassium chloride for use in electrolytic condensation hygrometers, measurements have been made during the year on the cryohydric and hydrate transformation temperatures of some of the alkali halides. Electrical methods have been used, allowing observations with only very small amounts of material. The technique of the electrolytic condensation hygrometer is also being applied in the systematic determination of the vapour pressures of the saturated solutions of a number of salts.

Work is in progress on the processes involved in the early stages of vapour condensation on a solid surface. Among other things, this may lead to a more complete understanding of the limitations of condensation hygrometry. It is already known that complications intrude at an accuracy not much higher than is often sought, namely, ± 0.1°C in the dew-point.

5. Viscometry

Viscometric developmental work has been leading both to improved standard procedures and to the provision of tools of general utility for industry. There has been continued research in the design of capillary viscometers incorporating long-flared capillaries which involve no significant kinetic energy effects and allow a simplification of routine accurate viscometry. Another new instrument, the viscosity ratiometer, which provides a ready indication of the ratio of the viscosities of two liquids, has been on loan to various industrial laboratories, where it has been found suitable for many purposes.

Preparations are being made for an improved determination of the relative viscosity of water at various temperatures; this will enable water to be used to provide a range of standard viscosities. The problem has been greatly facilitated by the development of the long-flared capillary viscometers, and some exploratory measurements have already been made with a reproducibility approaching 2 parts in 100,000. One of the main problems is achieving the accuracy necessary in temperature measurement. Suitable equipment for this is now being assembled.

6. Physical Aids to Surgery

Development of equipment for the extra-corporeal oxygenation of blood continued. The method favoured involves the flow of blood down a suitable helix in an oxygen atmosphere, and work has reached the stage where a spiral design has been established for quasi-optimum oxygenation rates. The Royal Alexandria Hospital for Children and the Division of Animal Health have cooperated in preliminary applied tests using a sheep as subject. Laboratory comparisons are also being made with a conventional type of oxygenator.

7. Photometry and Colorimetry

Steady demand continued for photometric calibrations, including standard lamps, photoelectric cells, photometers, and haemoglobinometers, and for measurements of spectral reflectance and transmittance. Demands for general spectrophotometry appear to be easing, probably because of wider availability of spectrophotometers. Special calibrations of unusual interest have included a deep-sea photometer and a low-level spectral radiation standard for use in the calibration of auroral recorders.

The Laboratory is at present taking part in an international intercomparison of photometric and colorimetric measurements on tubular fluorescent lamps, organized by the International Commission on Illumination and the National Physical Laboratory, Teddington.

Experiments continued on the optical properties of diffusing media. Studies of the effect of particle spacing on the reflectances of opaque diffusers have been extended to include dry pigments, i.e. diffusers having an air matrix. As with diffusers having liquid matrices, there is a general tendency for the reflectance to fall at high particle concentrations, presumably due to the interference of light waves scattered by neighbouring particles. The dependence of the reflectance of an opaque diffuser on the refractive index of the matrix is also being investigated experimentally.

Since spectral energy distributions are fundamental in many photometric and colorimetric contexts, including fluorescent lamp calibration, there has been continued attention to measurements of this type. Modifications have been made to the Division's G.E. recording spectrophotometer to permit rapid measurements (within 3–5 min) of spectral energy distributions over the visible range. This has proved particularly useful in the colorimetry of fluorescent materials. One disadvantage of the instrument is that the light source measured must be operated on D.C. A consequent investigation on tubular fluorescent lamps has shown that operation on D.C. instead of the normal A.C. makes negligible difference to the light emitted in the continuous spectrum, but seriously affects the contributions of the mercury lines.

The speed of the above instrument has facilitated spectral studies of the rapid changes in tungsten filament lamps during the first hour or so of burning. This has confirmed that the chief result of lamp seasoning is a non-selective lowering of the spectral emissivity of the filament.

8. Optics

The main emphasis in optics continued to be on the development of improved optical techniques and instrumentation.

Research continued on methods of measuring optical image quality in terms of the contrast transfer function, i.e. the contrast reduction produced by a lens system for each Fourier component of the object. The major equipment for this is now ready for final adjustment and testing. At the same time, a simpler version has been made for presenting results quickly on a cathode ray oscilloscope.

Attention has also been given to the problem of interferometer compensation. In general, high contrast interference fringes in a two-beam interferometer necessitate a point source of monochromatic light. But if two independent compensation conditions can be satisfied, the source can be enlarged and its spectral bandwidth increased. A method of adjusting for these two conditions independently has been tested on a Michelson interferometer, and means have been incorporated for detecting accurately when each condition is satisfied. This work provides a practical demonstration of the feasibility of compensation, a problem of general importance in interferometry.

Another interferometry development has been the use of a Fabry-Pérot monochromator to isolate a narrow band from the centre of the 5461 Å line from a mercury isotope lamp (^{198}Hg). When the monochromator has been used as a source for a Michelson interferometer, interference fringes have been obtained with path differences exceeding 4 m, far greater than with any natural spectral line. This investigation has demonstrated that monochromators of this type can be used to isolate narrow spectral lines usable over virtually unlimited path differences. Design of suitable equipment for utilizing the technique is now proceeding.

Following the successful installation of a simple "seeing" monitor on the 5 in. photoheliograph, to permit photography only when the edge of the Sun appears steady, further attention has been given to the problem of seeing in solar telescopes. Attempts are being made to develop a second type of monitor operating on the principle of testing the visibility of the fine structure of the solar surface. A separate investigation has concerned the possibility of eliminating troublesome image deterioration arising from atmospheric inhomogeneities within telescopes themselves. One possible method of overcoming this might be to control the temperature of the image space using the objective lens or a window as a thermal barrier. Investigations have been made of the effect of an axial temperature gradient across a plane parallel window, and it has been found that no significant distortion of an incident plane wave front occurs for differences of up to 50°C in the temperature of the air on either side of the window. However, bending of the window introduces a deviation of the rays which is negligible at normal incidence, but amounts to 0.45 sec of arc per °C temperature difference between the glass faces for an angle of incidence of 40°. Insignificant for astronomical work, this deviation could be of importance in the case of windows used in aerial survey cameras, where there can be appreciable temperature differences between the inside and outside air. The effects of turbulent inhomogeneities which arise near heated windows can be reduced to insignificant proportions by directing a stream of ambient air across each of the window faces.

9. Solar Physics

The very fine mottled structure visible on good-quality photographs of the Sun has long been thought to represent moving gas columns. In recent years the feeling has grown that transfer of energy between these columns and the tenuous, outer solar atmosphere controls the physical properties of these outer layers, which themselves control many phenomena directly affecting the Earth. The understanding of these granular features on the Sun has therefore become a matter of fundamental importance to solar and stellar physics, and to geophysics, and many investigators around the world have recently been devoting considerable attention to this problem.

This has become one of the Laboratory's main activities, and no doubt such emphasis will continue to characterize its solar research for some time. A more comprehensive program should soon be possible with the recently completed $\frac{1}{8}$ Å filter which will allow for determinations of velocities or magnetic fields at high angular resolutions over an appreciable area of the Sun. The more conventional spectrograph permits simultaneous observations only over a narrow strip on the Sun, but is able to cover a far wider wavelength range than is possible with the filter. For this reason designs are being studied for the future construction of a high-resolution telescope and spectrograph which, together with the narrow band filter and the white light photoheliograph, should provide a versatile set of basic instruments for investigations of features on the solar surface.

A limit to the fine solar detail which can be photographed is set by the shimmer or "seeing" due to fluctuations in the Earth's atmosphere. A seeing monitor has been put into operation for measuring image fluctuations and taking photographs at moments of acceptable seeing, and this has greatly reduced the time involved in record processing and analysis. Results obtained with it suggest that a larger telescope could probably be used with a seeing monitor to obtain photographs showing greater resolution than any obtained so far from ground observations.

During the year, particular attention has been devoted to granulation in sunspot umbrae. These are regions where the high magnetic field is expected theoretically to have a strongly inhibiting effect on convective motions. Observation has shown that the umbral granulation differs significantly from that observed in the normal photosphere, but much further work is needed before the causes can be explained. It has also been shown that the hot clouds of gas (faculae) which lie above sunspots are hardly, if at all, visible beyond the limb of the Sun; the reverse has sometimes been suggested. In confirmation of French observations, the photospheric granular pattern has been observed to within a few seconds of arc of the limb, a fact which has implications for the structure of the photospheric layers.

The flare patrol program continued until the end of 1959 as the Division's contribution to the extension of the International Geophysical Year (I.G.Y.). Data obtained have been sent to the World Data Centres, and this information, with selected copies of films, is now being used by these centres for preparation of data sheets on the I.G.Y. For the further study of solar flares, equipment has been constructed to investigate the mechanism of their white light emission.

Although the excitation of radiation in hot gases (e.g. the solar chromosphere) is not well understood, studies of this problem here and elsewhere have met with some success over the past few years. The broad features of the solution are now fairly clear. This theoretical work is continuing, and applications already made to solar and stellar observations give some confidence in its basic soundness. For example, on the basis of a high temperature chromosphere, a simple explanation has been found for the appearance (central reversal) of the H and K lines of ionized calcium in stellar spectra, and the main features of the helium spectrum of the solar chromosphere are now predictable.

10. Atomic Constants

Several modifications have been made in the apparatus used to measure the gyromagnetic ratio of the proton. The effect of building vibration has been greatly reduced. Electronic stabilization has been provided for the currents in (*a*) the electromagnet, (*b*) the balance measuring coil, and (*c*) the stray field compensating coils. The use of fixed coils, one on either side of the measuring coil, to eliminate or reduce the effect of the current in the measuring coils on the magnetic field has proved very satisfactory.

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Division of Electrotechnology

1. General

The Division of Electrotechnology is one of the three Divisions of the National Standards Laboratory (*see* Chapter 40). This Division is responsible for maintenance of the Commonwealth standards of measurement of electrical and magnetic quantities. It maintains the Commonwealth standard of measurement of frequency in conjunction with the Mt. Stromlo Observatory, and other standards derived from frequency, resistance, and electromotive force. The Division undertakes electrical and magnetic measurements on materials, and the calibration of instruments and equipment such as resistors, bridges, potentiometers, capacitors, inductors, indicating instruments, instrument transformers, signal generators, wavemeters, and fluxmeters. Investigation is being continued to improve and extend electrical measuring and standards facilities, and basic research is undertaken on the dielectric properties of insulating materials and microwave spectra of gases.

During the year Professor H. Fröhlich, Professor of Theoretical Physics at the University of Liverpool, spent 3 weeks in Australia at the invitation of the Division. The main object of the visit was to discuss and advise on the various aspects of the research of the Dielectrics Section. Particular attention was given to the interpretation of the results of several year's work on the dielectric properties of aliphatic long-chain compounds.

The Division has obtained the lease of an area of 6000 sq. ft. in a building less than half a mile from the main laboratory. The microwave and radio frequency sections have been transferred there to enable their activities to be expanded and to provide some relief from the general overcrowding in the Division.

2. Direct Current

(i) *Primary Electrical Standards*

The electrical units are not arbitrary like the metre, kilogram, and second, but are defined uniquely in terms of them by the laws of electromagnetism. The basic electrical standards must be pieces of equipment whose electrical properties can be calculated from their dimensions. These calculable standards are then used to calibrate other standards in the more convenient form of resistance coils and standard cells which must be stable enough to preserve the units in the intervals between such absolute determinations.

Several resistors of British manufacture have been under observation for a number of years as possible members of the group maintaining the national standard of resistance. Some of the resistors developed unusually rapid drift rates which were apparently due to faulty sealing of the containers. The more stable coils have now been resealed and, together with some recently acquired coils of American manufacture, have been formed into a new primary group. This will enable the coils which have been on loan from the National Physical Laboratory, and which until now have played a prominent part in the primary group, to be returned at an early date.

Several standard cells of the primary group were found to have developed a fast drift and were removed from the group. The value of e.m.f. represented by the resulting modified primary group was calculated, going back to the last verification by the National Physical Laboratory. Observation on several new cells has shown that few, if any, of these will be suitable for addition to the primary group. Further cells, specially selected, are now being obtained from British and American sources. In addition, the Physikalisch-Technische Bundesanstalt presented to this Laboratory a number of standard cells made by that Institute. These cells are at present under observation prior to their possible addition to the primary group.

(ii) *Low Frequency Measurements*

Investigation continued of the use of low frequency alternating current instead of direct current for precision resistance measurement. The performance of the detector amplifier used has been improved at very low frequencies, so that measurements are possible at frequencies down to 0.3 radian/sec. The sensitivity at frequencies down to approximately 1 radian/sec approaches the limits set by the thermal agitation noise of the resistance bridge connected to it.

Attention has been given to the effects of thermal noise and of changes of resistance with load and temperature on the limits of resistance measurement. For present types of standard resistors the limits due to these factors are found to be of the order of a few parts in 10^9.

The changes of resistance with frequency of a range of standard resistors are being measured to within approximately 1 part in 10^8 of their resistance values. To measure the corresponding D.C. resistance values a chopper amplifier has been constructed which has a sensitivity approaching thermal noise limits.

(iii) *Calibration Services*

The provision of a calibration service for the reference standards of other laboratories is the most important means of making the national electrical standards widely available in an effective manner. The demand for this service from industry, Government authorities, and universities continues to be considerable, and it has not been possible to accept D.C. calibration work of a lower order of accuracy.

The fairly large public demand for less precise calibrations should ultimately be satisfied by the various laboratories registered for this purpose with the National Association of Testing Authorities. In New South Wales the Sydney County Council and the N.S.W. Government Railways, both members of the Association, have been most helpful in trying to satisfy this demand.

3. Power Frequency

(i) *Instrument Calibration*

Further progress has been made on the new electrostatic voltmeter, the deflection of which is determined by electrical instead of optical means. Development of the 50 kc/s oscillator and amplifier necessary for this purpose has been completed, and a measuring accuracy better than 1 in 10^4 is easily obtained.

(ii) *Voltage Transformer Testing*

The original equipment as developed several years ago for voltage transformer testing was constructed as a number of separate units. It is now being rebuilt in a more compact and convenient form and the opportunity has been taken to effect a number of improvements. An extra ratio dial has been added to improve the accuracy. By means of a simple circuit modification the equipment can be used for measuring the values of burdens and also the leakage impedances of voltage transformers.

(iii) *High Voltage Measurements*

Previous work in this Laboratory has shown that crossed cylinders form a very convenient and accurate-measuring spark gap with considerable advantages over the more conventional sphere gap, particularly in the voltage range up to 140 kV.

Larger cylinders have now been made, and preliminary measurements have indicated that this gap is effective up to 450 kV r.m.s. This investigation was conducted in the new high voltage laboratory of the University of Queensland where facilities were very generously made available. Further work is planned when the Division's own facilities are extended to higher voltages.

4. Audio and Radio Frequency

(i) *Calculable Capacitor and Absolute Determination of the Ohm*

With the completion of the calculable capacitor attention has now been concentrated on the special equipment and components necessary to determine experimentally its characteristics and limitations as an absolute standard. Effort has also been devoted to the various techniques and devices required to derive the ohm from the standard capacitor with the minimum loss of accuracy.

(1) *Calculable Capacitor.*—A number of absolute capacitance determinations of a 0.25 pF fixed capacitor have been made using the calculable standard. The main purpose of these determinations has been to check the measuring procedures in detail, and in particular the method of determining the integral fringe count.

The calculated value of the standard is the change of capacitance brought about by the linear movement of an internal shield-tube. For a change of 0.25 pF the tube is moved through approximately 468,566 fringes (half wavelengths) of Hg green light. An exact count of these fringes is basic to the use of the standard. This fringe count has been done by a build-up procedure employing a series of fixed three-terminal capacitors of nominal values 0.002, 0.01, 0.05, and 0.25 pF. The number of whole fringes (3748) corresponding to the smallest capacitor is directly counted by an electrical technique and the odd fraction of a fringe is determined by substitution. When this capacitor is accurately known in terms of fringes it can then be used five successive times to adjust the calculable standard to an exactly known number of fringes in the neighbourhood of the 0.01 pF capacitor. The small remaining difference in fringe value is directly determined by substitution of the calculable for the 0.01 pF capacitor. The value of the 0.01 is thus known in terms of a whole number of fringes plus a fraction. This process is repeated with each capacitor until the fringe value of the 0.25 pF capacitor is determined.

In any redetermination it is sufficient to commence the build-up from the largest capacitor whose integral fringe value is known with certainty. Experience so far indicates that sealed 0.25 pF capacitors can be made sufficiently stable for this purpose, so that the build-up process in future may not be necessary.

Tests to determine the frequency coefficient of the calculable standard have shown that it is small, but its precise determination is still in progress.

(2) *Absolute Determination of the Ohm.*—Very stable components and precise measuring assemblies are required to relate the value of 1 ohm resistance standards to the calculable capacitor. The measuring assemblies must have a sensitivity of 1 in 10^7 and all corrections must be evaluated to this order. The development and testing of components and assemblies is proceeding steadily.

Capacitors.—A number of small three-terminal capacitors of various designs have been constructed and subjected to temperature cycles to determine their temperature coefficients and stability. These tests have indicated some constructions which must be avoided if high stability of the order of 1 part in 10^7 is to be maintained. For example, joints between materials of different temperature coefficients of linear expansion are a frequent cause of mechanical instability. Because of the need to insulate the electrodes it is difficult to avoid such joints, but it is generally possible to produce a design in which the mechanical stability of the joint is not of first order importance. One type of joint showed a considerable improvement in stability. In this design the electrodes are supported by three small synthetic sapphire spheres.

A special jig has been constructed to determine the temperature coefficients of linear expansion of the various materials used in the construction of capacitors. The sample is in the form of a cylinder 1 in. long and $\frac{1}{2}$ in. in diameter and forms the inner electrode of a coaxial capacitor. By measuring the change of capacitance with change of temperature the temperature coefficient of linear expansion of the sample in the radial direction can be determined.

This development work has been successfully concluded by the construction of a number of capacitors of low temperature coefficient and very high stability in the range 0.002–10 pF, and attention is now concentrated on capacitors of larger value.

Resistors.—Resistors of special construction have been made such that their frequency coefficients of resistance are very small. These are used as standards for determining the frequency coefficient of other four-terminal resistors. Exhaustive tests have been carried out on the bridge network used over the frequency range 50–5 kc/s. Modifications have been necessary to reduce the frequency coefficient of the bridge assembly itself to acceptable limits.

Transformer Ratios.—Very precise transformer ratios are used in many of the measuring assemblies, and methods are being developed to test their accuracy. In one method a specially shielded winding is added to the transformer, and individual sections of the main winding are compared separately with this floating winding. A complete assembly of this type has been constructed and is being tested.

(ii) *Frequency Measurements*

(1) *Frequency Standard.*—A third oscillator using an Essen ring crystal has been placed in service and the rearrangement of the frequency standard has been completed. The three oscillators have been compared with each other, and the largest value of the short-term frequency variations shown by the intercomparisons is about 1 in 10^{10}. An attempt to correlate these frequency changes with changes in the amplitude of oscillation did not give any positive result.

The very stable 16 kc/s radio transmissions from G.B.R. Rugby continue to be received, and equipment is being constructed to present the information so obtained in the most useful form. A servo-controlled phase-shifter has been developed to follow the phase of the received signal, and a mechanical printer is being constructed to print directly the phase at appropriate time intervals.

Experience to date indicates that such low frequency transmissions can be used to relate the Australian frequency standard to the National Physical Laboratory caesium resonator to an accuracy of 1 in 10^9.

(2) *Microwave Frequency Measurements.*—The equipment for generating a stable signal, for use as a starting point for multiplication to microwave frequencies, has been extended. This permits the generation of other frequencies differing by an adjustable amount from that of the 10 Mc/s oscillator locked to the mean frequency of the 100 kc/s standard.

When completed, this extension will permit the selection of any one of 1000 frequencies at 0.01% intervals around 10 Mc/s, still locked relative to the mean frequency of the 100 kc/s standard, but isolated from it as far as noise and modulation products are concerned.

(iii) *Impedance Standards for Very High Frequencies*

The increasing use of very high frequencies commercially in such fields as television and navigation has created a demand for a calibration service for the various measuring instruments involved. One of the most important quantities to be measured is the impedance of the transmission circuits and components in use.

Several types of commercial instrument are available for this purpose, the best of which are capable of an accuracy of a few per cent. Standards accurate to 1% or better are desirable to calibrate these instruments.

An absolute reference standard has been developed in the form of a coaxial line system of 50 ohms characteristic impedance which is calculable from the mechanical dimensions. An adjustable load has been developed enabling precise matching of the system to be achieved over the range of 30–1000 Mc/s.

One of the main limitations in the uses of such standards is the additional errors introduced by connectors. Equivalent circuits can be established and allowance made for connectors to the extent that their performance is repeatable on making and breaking the connexion. The best available commercial connectors do not give adequate repeatability for standards and calibration work. A special connector has been developed for the purpose.

(iv) *Screened Rooms*

The screening efficiency of screened rooms has been investigated, with particular emphasis on the microwave part of the spectrum.

(v) *Microwave Spectroscopy*

A theoretical investigation has been made of the magnetic interactions occurring within asymmetric rotor molecules. This is being applied to the interpretation of the measured magnetic interaction constants of the deuterated water molecules.

The theory of the shapes of absorption lines has been extended to include the effects of dependence between Doppler and pressure broadening.

(vi) *Random Noise*

Studies of probability problems associated with various random processes have been carried out experimentally with the probability distribution analyser designed and constructed in the Division. Attention has been devoted to a random process which occurs in neurophysiology. A microelectrode implanted in the appropriate part (lateral geniculate of the thalamus) of the brain of a cat may be used to detect the firing of an individual nerve cell forming part of the nervous system connected with vision. The firing of such a cell occurs largely at random, with statistical properties which are influenced by the visible radiation falling on the retina.

A tape recording of the microelectrode response is made, and its statistical properties are then determined by the probability distribution analyser. A number of different types of nerve cells have been investigated under many conditions of retinal illumination. This work has been done in collaboration with members of the Physiology Department of Sydney University.

5. Magnetics

(i) *Uniform Field Coils*

Most magnetic tests require a uniform magnetic field, and equipment for this purpose is essential in a modern magnetics laboratory.

A system of four coils for producing a field in air uniform to 0.1% throughout a volume of 1000 c.c. has recently been completed. This volume of uniform field is several times larger than that given by a conventional two-coil Helmholtz system of the same size. The coils and their mounting are free from ferromagnetic materials and can be orientated readily in any chosen direction.

The equipment will be used for magnetometer calibration, area turns measurement, measurements of the Earth's field, and proton resonance experiments.

Tests for normal induction and hysteresis on bars, rods, and strips also require a high degree of field uniformity. The Division's yoke permeameter has been improved in this respect by the addition of new end coils and a "field uniformity" coil, which enable the field uniformity to be controlled independently of the main field.

(ii) *High Sensitivity Fluxmeter*

A highly sensitive and stable fluxmeter has been developed by the application of feedback techniques to a galvanometer modulator.

A differentiating feedback loop is used to make the galvanometer function as a fluxmeter and, as the output from the modulator is A.C., high sensitivity can be achieved by electronic amplification. The limit to sensitivity is then due to unavoidable thermal e.m.f.'s in the input circuit which give rise to slow drifts in the output. In this instrument the drifts are controlled by an additional resistive feedback loop which automatically off-sets the thermal e.m.f.'s and adjusts the instrument zero before a measurement. The only drift error remaining is that which occurs during the few moments required to take the measurement.

6. Dielectrics

(i) *Alkali Halides*

Study on alkali halide crystals containing divalent cation impurities continued. It had previously been shown that the dipoles resulting from the association of the impurity ions and vacant positive ion sites gave rise to dielectric loss. The characteristics of the loss gave valuable information about the energy barrier in the crystal and also the degree of association existing. Variation of the loss with time also indicates the rate at which the single dipoles aggregate into higher complexes. This effect has now been studied in potassium chloride with either barium or strontium as the impurity ion. The measurements revealed several unexpected features of aggregation kinetics.

(ii) *Aliphatic Long-Chain Compounds*

The main research effort on these materials has been devoted to growing large single crystals and the production of purer compounds.

(1) *Crystal Growth*.—The furnace for growing crystals by the Bridgman method has been improved in several respects. In particular, its temperature stability is considerably better and the rate at which the crystals can be cooled to room temperature is also controlled. In general it has been found that material

which has been through the zone refining process yields improved crystals. Whilst the single crystals grown so far are not as large as desired, some useful dielectric measurements have been made on them.

(2) *Zone Refining.*—The zone melting process has been explored to increase the purity of aliphatic organic compounds. Zone refining methods are much slower in these compounds compared with the spectacular results achieved with semiconductors. The molten zone must travel much more slowly and many more passes are required. Another interesting fact is that in contrast to distillation methods the long-chain fatty acids are purified more readily by this method than their methyl and ethyl esters.

(iii) *Hydrates of Calcium Sulphate*

In cooperation with the Division of Building Research, dielectric measurements were made on samples of calcium sulphate hydrates in the hope of obtaining useful structural evidence. Gypsum was the only compound available in suitable form for measurements on single crystals. A slice normal to the "b" axis gave negligible absorption. Large absorption was obtained, however, when the powder forms of gypsum and the α- or β-hydrates were pressed to form disks. This absorption varied with time and was probably due to water liberated as a result of structural damage on pressing.

(iv) *Theory of Dielectric Loss*

A general theoretical treatment of Debye loss has been initiated by attempting a finer statistical mechanical analysis of molecular behaviour. In this, not only is the distribution of energies sought, but also their rates of change due to irregular internal forces and the external electric field. Preliminary results show that the statistics of the latter have important consequences in relaxational problems.

(v) *Theory of Superconductivity*

Interaction of conduction electrons and lattice vibrations in a metal has been shown to lead to two alternative types of phonon motion. A model of a metal has been investigated in which these two types of phonon motion are taken as describing respectively a normal and a superconducting phase of a metal. Features of the latter state predicted by the model are absence of real electron-phonon collisions, and an exponential temperature dependence of the difference in specific heats. The treatment has been shown to be gauge-invariant, and the "superconducting" state appears to show a Meissner effect.

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Division of Radiophysics

1. General

The Division of Radiophysics in Sydney carries out research in fields to which modern radio and radar techniques have particular application. These include rainmaking and radio astronomy, which are new studies developed with the aid of electronics. In these fields the use of higher frequencies and pulse methods has provided unique research tools previously unavailable. The Division is also concerned with development of specialized techniques and equipment for use in radio astronomy observations, and its program also includes work on semiconductors, radio aids to navigation, and propagation of radio waves.

Electronics has assumed increasing importance in science and technology, and development of electronic equipment for various research purposes is undertaken in many C.S.I.R.O. laboratories. The following Divisions and Sections are carrying out investigations in fields allied to projects in progress in the Division of Radiophysics: the Upper Atmosphere Section at Camden studying electromagnetic phenomena in the upper atmosphere of the Earth (*see* Chapter 45); the Division of Physics studying solar radiation and solar physics (*see* Chapter 42); the Division of Meteorological Physics, which is the major centre within C.S.I.R.O. for study of the science of meteorology (*see* Chapter 46); and the Division of Physical Chemistry studying ice nucleation in relation to the basic physics of rainmaking (*see* Chapter 30).

Good progress is being made by the Division of Radiophysics in the construction of the giant radio telescope at Parkes, N.S.W. The contract for the construction of the telescope was placed during the year with the West German firm of Maschinenfabrik Augsburg-Nürnberg A.G. The reinforced concrete tower on which the telescope is mounted has already been completed on the 410 acre site near Parkes, which was purchased last year. The contract calls for the instrument to be completed in readiness for acceptance tests early in 1961, and there is every indication that this schedule will be met.

Large-scale rainmaking experiments, designed to establish to what extent rainfall in typical areas of Australia may be increased by seeding clouds with silver iodide from aircraft, have continued in the Northern Tablelands of New

South Wales and the Darling Downs, Qld., and a new trial has been commenced over the catchment area of the Warragamba Dam, west of Sydney. The Snowy Mountains experiment concluded after 5 years' operation and the final results are being computed.

2. Cloud and Rain Physics

The demonstration, in 1947, that some types of cloud could be induced to rain by seeding them with dry ice led to the inclusion, in the Division's program, of experimental and theoretical studies of the physical processes responsible for the formation of cloud and rain.

One objective — to provide a background against which the feasibility of artificial rainmaking might be properly assessed — has largely been achieved. An important aspect of current work is a series of large-scale rainmaking trials designed to establish to what extent cloud seeding with silver iodide from aircraft can be expected to increase rainfall in typical areas of Australia.

The Division's earlier work established the vital part played by atmospheric nuclei in initiating both Bergeron-type and coalescence-type rain. Studies continued of the nature and occurrence of the naturally-occurring nuclei responsible for initiating the rain-forming process in supercooled clouds. Investigations of the physical processes involved in the formation of clouds and in determining their effectiveness as rain-producers have been continued.

(*a*) *Cloud Formation and Properties*

Measurements of the properties of cumulus cloud have indicated that substantial mixing must occur between the rising air parcel responsible for cloud development and the clear air environment through which that parcel rises. The nature of the mixing process is, however, at present unknown and studies to determine this have commenced. A technique has been developed which shows promise of yielding information on the cloud levels at which most mixing occurs. This has been applied to the results of preliminary observations, and some mixing appears to take place between the dry air above cloud top and the cloud itself. However, to be certain of this, the accuracy of the instruments used must be improved and this is now being done. To reduce the observations fully an enormous amount of computation is necessary, and a program has therefore been devised to enable future results to be reduced on an electronic computer. In addition, work is being carried out to simplify the present method of preparing the data for electronic computation.

Many measurements have now been made of the concentration of condensation nuclei active at the small supersaturations that occur in natural clouds. Direct comparisons have also been made between these nuclei concentrations, and the numbers of cloud droplets in cumulus cloud formed in different types of air mass. It has been confirmed that air which has been over the continent for some days is rich in these nuclei, and clouds forming in this air contain large numbers of small droplets. These clouds are stable, and produce rain only with difficulty, unless they become deep enough and cold enough for ice crystals to form. On the other hand, maritime air has low concentrations of nuclei, and maritime cloud has much smaller numbers of cloud droplets with a bigger range of sizes, which can collide with each other and grow to raindrop size more readily. These are the clouds which produce rain very easily. Differences in cloud behaviour in relation to rain formation are thus primarily caused by those nuclei which are picked up by the air mass as it travels over the continent.

A laboratory experiment has been made which supports the conclusions of an overseas theoretical study of the motion of individual droplets, namely, that droplets of diameters less than 36 μ are incapable of collecting any smaller ones in their path. Since continental clouds do not contain significant numbers of droplets as large as this but maritime clouds do, and the collision and coalescence process is the only one active in warm clouds, the reason for their difference as rain producers is clear. Further laboratory studies indicate that strong electrostatic fields can profoundly alter the behaviour of these small uncharged droplets, and cause collisions which would otherwise not occur.

(*b*) *Natural Ice Nuclei*

Naturally occurring ice nuclei in the atmosphere have been studied by means of a continuously operating automatic cold box, and the results have provided an understanding of some of the sudden and spectacular increases in the concentrations that have been observed.

The source of the nuclei has not yet been established by direct observations, but periods of unusually high counts again had a good degree of coincidence with the dates of rainfall singularities discovered by Bowen. It has also become clear that some of the changes in nucleus count are associated with the sudden breakdowns of temperature inversions at which nuclei have become trapped.

An automatic "gate" on the instrument has made it possible to sort the nuclei into size ranges, and to determine the proportion which are magnetic. Over a total period of 1000 hours' operation (excluding periods when the concentration was fluctuating), about half the nuclei were larger than 1 μ in diameter, while one-third were ferromagnetic.

The concentration may vary by a factor of 10 in less than a metre of height in the vicinity of temperature discontinuities near the ground on calm nights.

(*c*) *Artificial Stimulation of Rain*

Major effort has been concentrated, as in previous years, on experiments over large areas. Experiments have also been made on seeding individual clouds, and development of freezing nucleus generators. A program of physical verification also commenced in connexion with one of the large-scale experiments.

During this year five large-scale experiments have been in operation in which silver iodide smoke is released from aircraft into clouds to determine the effect on the rainfall over areas of 1000–3000 sq. miles. Aircraft used have included three Cessna 310B's, two owned by the Division and one chartered from Rex Aviation, and a Beechcraft Twin Bonanza and a Lockheed Hudson, both chartered from East-West Airlines. Seeding of individual clouds and other experiments have been carried out in a DC-3 aircraft of Detachment "B" of the Aircraft Research and Development Unit (A.R.D.U.) of the Royal Australian Air Force.

(i) *Large-Scale Experiments*

(1) *The Snowy Mountains Experiment*.—This experiment was continued, in cooperation with the Snowy Mountains Hydro-Electric Authority, until November 1959, when the planned 5 years' operations were completed. It was restricted to the winter seasons, extending from March to November inclusive. Clouds over a "seeded" area of about 1000 sq. miles were seeded with silver iodide smoke released from a specially equipped aircraft. There is a small "target" area in the middle of the seeded area where the effects of seeding should be most pronounced. The precipitation in these areas was compared with that in an adjacent "control" area. The seeding season was divided into periods of about 2 weeks' duration. During the whole of any one period clouds over the target area were or were not seeded, the choice of whether or not to seed being made on a random basis. The relation between the natural rainfall in the target and control areas was determined during the unseeded periods.

During October and Novemebr 1959 the experiment was assessed by Professor Roscoe R. Braham Jr., of the University of Chicago. Professor Braham's report, based on the first 4 years' operations, included the following two main conclusions:

"1. From an overall point of view, I consider this experiment to have been a good one. It was well designed and well carried out, except for the matter of drawing the isohyets." (See below.)

"2. I conclude that it is very likely that there were increases in precipitation in the Snowy Mountains as a result of seeding . . . In my opinion the 20% sample mean is probably substantially larger than the real increase due to seeding."

The "matter of drawing the isohyets" refers to Professor Braham's discovery that the individual who drew the isohyets knew which periods were seeded and was thus, in theory, capable of biasing the results. The isohyets are therefore being redrawn by an independent authority and the final conclusions from this experiment will not be known until the revised figures have been analysed.

Preliminary figures based on the original isohyets indicate that in the seeded periods there has been more rain in the seeded and target areas than would have been expected, judging by the rain in the control area. The magnitude of the increase has been 18 and 10% for the target and seeded areas respectively. The statistical significance of these preliminary results has been computed in a number of ways, some of which have been developed for the purpose; it is about 1% for the target area and 3% for the seeded area.

(2) *South Australian Experiment*.—The second large-scale experiment took place in South Australia in the hills north of Adelaide, in two areas each of about 1000 sq. miles. Clouds over one of the two areas were seeded with silver iodide smoke released from an aircraft during the whole of a period of about 2 weeks,

the choice of which area to seed in any period being made on a random basis. This procedure should increase the ease of detection of the results of seeding compared with that used in the Snowy Mountains experiment, where only one area was seeded on an on-off basis.

The South Australian experiment, which was restricted to the winter months, commenced in April 1957 and was terminated in October 1959. In the 3 years of operation there was no evidence that the seeding had any influence on the rainfall, most of the clouds encountered being too warm to be affected by silver iodide. Evidently most of the rain in this area during these 3 years fell by the coalescence process, and this would be a good area in which to test methods designed to stimulate this process. A Cessna 310B was again used in the 1959 season.

(3) *New England Experiment.*—An experiment similar to that in South Australia was commenced in New England in February 1958, in two areas of 2000–3000 sq. miles centred respectively on Tamworth and Inverell. This experiment runs all the year round except for the months of November and December, when it is suspended during the period of the wheat harvest. The first year's operations were very promising, and substantial rainfall increases appear to have accompanied seeding. In the second year, however, the increases were quite small. Only preliminary results are available for the first portion of the third year, but these indicate that increases have again accompanied seeding.

Aircraft employed on this project have included a Cessna 310B, and a Beechcraft Twin Bonanza. A Hudson has been used during the temporary unserviceability of the Beechcraft. The experiment will continue for at least 4 years.

(4) *Darling Downs Experiment.*—An experiment similar to that in New England was started in the Darling Downs of Queensland in two 2000–3000 sq. mile areas centred on Warwick and Dalby. It is planned to run from December 15 each year (when wheat harvesting ends) to a date not yet settled. The experiment began in February 1959 and continued until May 30; in this year plenty of apparently suitable clouds were encountered, and the area appeared to be satisfactory. Operational difficulties were experienced, however, and no results were achieved. The start of the second year's operations was postponed until January 7, 1960, by the "referee" because of excessive rainfall. Since then drought conditions have prevailed, and there have been fewer clouds than in the previous year, so that no results are yet available.

(5) *Warragamba Catchment Experiment.*—An experiment, in cooperation with the Sydney Water Board, began over the catchment area of the Warragamba Dam, a major storage for Sydney's water supply, in December, 1959. It is similar to those described above except that the seeding period is of 1 day's duration, which will make it possible to analyse separately the effects of seeding in maritime and continental air, both of which bring rain to this area. So far, conditions suitable for seeding have occurred only in continental air.

(ii) *Stimulation of Individual Clouds*

(1) *Amount of Silver Iodide.*—Individual clouds are being seeded with silver iodide smoke to determine the relation between the number of freezing nuclei

supplied and the amount of rain stimulated. A DC-3 aircraft of Detachment "B" of A.R.D.U. is fitted with two silver iodide burners which produce freezing nuclei at a different rate. A cloud is selected and seeded with either the large burner, the small burner, or no burners at all, on a random basis. The quantity of rain which falls thereafter is determined by suitable instruments as the aircraft flies through it. It has not been possible to devote much time to this project, and suitable clouds have been rare during this year. Further experiments are required before any conclusions can be drawn.

(2) *Electrostatic Charges.*—Seeding clouds with silver iodide may cause changes in the electrostatic field around and within the cloud. Apparatus developed to measure these charges has been fitted to the DC-3 used in the single cloud experiments. It has been operated several times but, so far, no significant results have been achieved.

(iii) *Physical Verification*

If a large-scale cloud-seeding experiment is successful, various physical atmospheric parameters will be affected as well as the rainfall. A program has been commenced to measure as many of these quantities as possible in both the seeded and the unseeded areas of the Warragamba experiment. In the first instance the concentration of freezing nuclei, the temperature, and the electric field will be measured by instruments in a DC-3 aircraft of A.R.D.U.

3. Radio Astronomy

Specialized radio telescopes already developed by the Division have been used throughout the year to study radio frequency radiation from the Sun, from within our own galactic system, and from external galaxies.

Good progress has been made with the construction of the 210 ft diameter steerable parabolic "dish" being erected on a 410 acre site near Parkes, N.S.W., and this instrument is expected to be brought into operation during the coming year.

(*a*) *Radio Waves from Beyond the Solar System*

(i) *Investigations at* 3.5 *Metre Wavelength*

Previous reports described the survey of the southern sky with the 1500 ft Mills Cross. This is now complete, and a second survey utilizing parts of the instrument converted for angular size measurements is almost complete. The conversion involved the addition of an extra aerial at a great distance to form a two-element interferometer; sizes in the range of 10–60″ of arc can be measured. Reduction work remains to be done before the final results of the angular size survey can be evaluated. One interesting result is the observation of many radio sources with angular sizes less than 15″ arc. These appear to be "radio galaxies" further away than the most distant galaxies observed with optical telescopes. The application of these results may have great cosmological significance.

The principal analytical work has been the further compilation of catalogues of radio sources, a task now practically complete. Two catalogues, together containing more than 2000 radio sources, are finished, and the third and last catalogue planned is in the final stages of preparation. Detailed study of a large number of possible identifications of radio sources with galaxies, and clusters of galaxies, has led to interesting results. The idea that many, possibly the majority, of radio sources, are associated with interacting pairs of galaxies has been confirmed and, more important, it has been possible to take the first steps in deriving a "radio luminosity function" of galaxies. It appears that the proportion of galaxies having a given radio emission falls rapidly with increasing emission, and that any random sample of radio sources contains members of all observed emissivities, a range of about $10^7 : 1$. This result suggests the impossibility of applying radio astronomical data to cosmology without the availability of the angular size measurements necessary to study separately the very distant sources of high emission.

A question which has exercised the minds of radio astronomers for a long time concerns the possibility of detecting and studying radiation from stars other than the Sun. An experiment is now under way, using portion of the original "Mills Cross" which is not involved in the angular size program, to keep under observation, for a few hours each day, the nearest star, α Centauri. The hope is that outbursts of radio noise similar to those produced by the Sun in periods of great sunspot activity may be recorded. Because such outbursts from the Sun are infrequent, a long time may be needed to obtain significant results either of a positive or negative character.

(ii) 15-*Metre Cross Aerial Observations*

A contour map of the galactic plane has been drawn using the results of several years' observations, and is now substantially complete for an area 10° wide extending between galactic longitudes 225 and 15°. Within this area there is remarkably good agreement between "radio-dark" regions and optically observed HII regions (suggesting that radio observations might be used to locate other HII regions whose optical identification has been hampered by obscuration). A few strips of sky still require further observations. These are in high southern declinations where interference from short-wave transmitters limits the amount of useful observing time. This last stage of the survey is now almost complete.

Ionospheric refraction measurements, a necessary adjunct to the galactic survey, have proceeded simultaneously with it. On the basis of refraction theory, and by using electron density data from a number of ionospheric sounding stations, it has been possible to correct the observed positions of several radio sources and bring them into good agreement with the positions measured at higher frequencies.

(iii) *Polarization Studies*

Current theory of the origin of the main component of cosmic radio waves (excepting the 21 cm hydrogen line), is that they are emitted by very high energy electrons, of energy comparable with cosmic ray particles, moving in interstellar magnetic fields ("synchrotron" mechanism). This theory predicts that the radiation should be completely plane polarized at the point of origin, though the received radio waves, which come from points distributed over a large region, might be more randomly polarized. Most attempts to measure the polarization of cosmic radio waves have yielded a zero result, excepting for the Crab Nebula, but 3% polarization over large regions in the sky remote from the Milky Way has been reported by Russian workers. Such measurements are technically difficult. An attempt was made to check this result, but over the region of the sky examined no resultant polarization was observed greater than the experimental uncertainty which was about 1%.

(iv) *Observations near* 21 *Cm Wavelength*

Two different sets of observations have been made in the continuum near 21 cm wavelength. In one, the 36 ft transit parabola at Potts Hill has been used to construct contour diagrams of the emission nebula η Carinae and the galaxy NGC5128; these have been compared with earlier 3.5 and 15 m contour diagrams of the same objects. Also a series of high-resolution brightness distribution studies of various galactic and extragalactic objects has been made using the aerials of the Christiansen cross-grating interferometer. The radio source Centaurus A (NGC5128) is common to all observations and some very interesting results have emerged. Previously it was known that the source comprised an inner bright region and an extended corona, both elongated and disposed approximately at right angles. Now it appears that each of these components splits into two separate concentrations more or less symmetrically situated about a common centre. The general picture does not change appreciably over a wide range of frequencies, the only obvious difference occurring at 19.7 Mc/s, where it appears that radiation from the small central components may undergo absorption by HII regions within the Galaxy.

(v) *Hydrogen Line Studies*

Detailed results of the 21 cm survey of the Southern Milky Way have now been published. These results, together with corresponding information from Leiden Observatory, were used by a Sub-Commission of the International Astronomical Union as the primary evidence for the choice of the new system of galactic coordinates. This is believed to be the first occasion on which a major astronomical decision has been based almost entirely on radio data. A series of papers has been written by a group of Australian and Dutch astronomers, discussing the new system and giving the evidence on which it is based; these will be published shortly.

Work continued on a spiral structure diagram for galactic hydrogen. The velocity model which was used in the reduction of the northern observations from Leiden gives implausible results when applied to the southern data. A more reasonable diagram is obtained when somewhat lower rotational velocities are used. Comparison between the two velocity curves suggests that the expanding motion, which has recently been discovered in the inner parts of the Galaxy, may extend out to the Sun's distance from the centre.

The whole visible sky has now been surveyed with the 48-channel receiver, using a low-resolution aerial (2.2° beam). Results have been published for two particular regions, and those for several other regions have also been analysed, with particular emphasis on the distribution of neutral hydrogen away from the galactic plane. Of special interest is a chart of the velocity distribution of the "local" hydrogen, which indicates the general nature of the circulation of gas in the local spiral arm.

To take proper advantage of the rapid rate at which the multi-channel receiver gathers information, digital equipment has been developed so that the recorded data can be reduced by an electronic computer. A new survey of the Magellanic Clouds is being undertaken as a pilot experiment with the digital system.

(*b*) *Solar Radio Waves*

(i) 64 *Element Crossed-Grating Interferometer*

Routine observations have been continued, an attempt being made, as far as possible, to "see" the Sun on at least each alternate day. Two types of observations are made: with the full cross (for 20 cm radio isophotes of the Sun with a beamwidth of about 3′); and with one arm of the cross (for strip-scans across the Sun from east to west or from north to south). The latter type of observation is continued for several hours daily with the object of observing bursts.

Reduction of records has been concentrated on the period covered by the International Geophysical Year, for which radio isophotes derived here are to be published on a lavish scale, superimposed for comparison with other types of solar observations.

The heights above the photosphere of a number of the emitting regions have been calculated, and a comparison with similar measurements of the same regions being made in Japan at 10 cm wavelength is in progress. Approximately a dozen large bursts have been observed, and on many days a large number of very small bursts of short duration (under 1 sec) has been observed.

Records taken in 1958 with this equipment have been used during the past year for an investigation of the thermal radiation from the "quiet" Sun. The high angular resolution makes it possible to isolate this component from the enhanced radiation due to localized sources. Quiet-Sun radiation increases in intensity towards sunspot maximum, and the corresponding brightness temperature is greatest in the equatorial regions of the Sun.

The 20 cm observations made during the eclipse of April 1959 have now been analysed. They provide independent confirmation of the above conclusions on the quiet Sun. They also give very clear evidence for a one-to-one correspondence between the chromospheric faculae and the regions of origin of the slowly varying component of the decimetre-wavelength radiation.

(ii) *Solar Radio Disturbances at Metre Wavelengths*

New equipment has been developed and installed to allow the continuous measurement of the angular size of the sources of solar radio bursts at wavelengths of 5 and 7.5 m. This equipment is now operated regularly in conjunction with the radio spectrograph (which records the dynamic spectrum of the bursts in the wavelength range of 1.4–12 m), the swept-frequency interferometer (which records the positions of the sources of bursts in the wavelength range 4.3–7.5 m), and further equipment which records the polarization of the emission over the latter wavelength range. A comprehensive set of data for each recorded solar event is thus being obtained for use in investigating a wide variety of problems. The data are also published regularly in the *Quarterly Bulletin of Solar Activity*.

With the aid of these techniques a detailed investigation of the physical nature of type III radio bursts has been completed. Direct confirmation has been obtained of the hypothesis that the sources of these bursts move rapidly outwards through the solar atmosphere, emitting different frequencies at different heights. The mean measured velocity was found to be about $0.4c$ (where c is the velocity of light). Many of the bursts are followed by a distinctive phenomenon ("type V bursts") consisting of continuum emission, bearing all the hallmarks of synchrotron radiation from relativistic electrons in a magnetic field. The conclusion was drawn that the combined type III-V event is due to the propulsion, at the starting time of flares, of clouds of electrons containing the order of 3×10^{33} electrons with energies of the order of 2 Mev. As they travel outwards in tight spiral paths they are responsible for radio emission of two kinds: emission due to excitation of plasma oscillations in the surrounding coronal gas (the type III burst), and by direct emission of synchrotron radiation (the type V burst). If the explanation is correct, these phenomena appear to have revealed the most frequent and prolific known source of relativistic electrons from the Sun.

Editing continued on the world-wide observations on solar radio emission, for publication in the *Annals of the International Geophysical Year*, and in the issues of the *Quarterly Bulletin of Solar Activity* issued by the International Astronomical Union.

(c) *Receiver Techniques*

Within the past few years two new types of "low-noise" amplifier appeared, which promise a reduction in internal receiver noise (and hence an increase in sensitivity) by one or two orders of magnitude. These are thus of particular interest for radio astronomy applications. The new techniques involve the use of "maser" and "parametric" amplifiers, respectively. Development of receivers of both types is in progress within the Division. Work on more conventional receivers is also being carried out to improve the performance of multi-channel hydrogen-line equipment, and to develop suitable preamplifiers to enable the cross-grating interferometer to be used for galactic work.

(i) *Masers*

A package maser for 1400 Mc/s has been developed in collaboration with the Division of Physics and is at present being tested on the 36 ft Potts Hill aerial. The maser uses ruby (Al_2O_3 with 0.05% Cr_2O_3) as the active material, giving amplification when "pumped" with power at 11,000 Mc/s. With the apparatus cooled with liquid helium to 4°K a gain-bandwidth ($G^{\frac{1}{2}}B$) product of 3×10^7 has been obtained. The product of the bandwidth, B, and the square root of the power gain, G, is a constant and a figure of merit for negative-resistance amplifiers; a $G^{\frac{1}{2}}B$ value of 3×10^7 gives a bandwidth of 3 Mc/s with a gain of 20 dB, which is sufficient gain to make the noise of the subsequent receiver unimportant. The overall noise temperature of the installation should be about 70°K, with the maser itself contributing under 10°K.

The overall weight of the maser unit installed at the aerial focus has been kept down to 140 lb, which the aerial can bear with safety. The heaviest item is the electromagnet required to produce a uniform magnetic field of around 2000 gauss inside the ruby. Auxiliary components for handling helium in the field have been made. Liquid helium will be taken out in a special Dewar flask, and the gas will be collected after evaporation, compressed into cylinders, and returned for subsequent reliquefaction.

At Harvard University, Mr. B. F. Cooper, Principal Research Officer on leave from the Division, has played the leading part in developing a 1420 Mc/s maser for radio astronomy. With its aid hydrogen-line radiation from a number of external galaxies has been discovered.

(ii) *Parametric Amplifiers*

Limited investigation of parametric amplifiers was carried out during the year. The up-converter from 250 to 9,000 Mc/s described in last year's report was not carried to the aerial stage, but it could have application in radio astronomy when improved "varactor" diodes become available.

Dr. B. J. Robinson, Research Officer stationed at Leiden, Holland, has played a leading part in developing what appears to be the first parametric amplifier sufficiently stable for radio astronomy. It is being developed into a complete hydrogen-line receiver for external galactic investigations, and a duplicate is being made, partly in Holland and partly in Sydney, for use with the 210 ft radio telescope at Parkes.

Mr. A. G. Little, Research Officer on leave from the Division, has been working on parametric amplifiers at Stanford University.

(iii) *Multi-Channel Hydrogen Line Receiver*

To make full use of the potentialities of the 210 ft radio telescope for observing the neutral hydrogen line at 1420 Mc/s, it has been found necessary to rebuild the existing multichannel receiver. The new receiver will include features based on the requirement of the much larger telescope and on the large amount of experience which has been gained in operating the present model at Murraybank. The main features of the new design are: much greater spectral range and resolution; the ability to make accurate spectral measurements in the presence of the high source intensities expected; and a very much faster recording rate.

(iv) *Interferometer Equipment*

Preamplifiers are being developed for fitting to individual aerials of the crossed-grating interferometer. These should provide improved sensitivity so that the east-west arm may be combined with the 60 ft Kennedy steerable aerial for galactic work. The requirement is for a simple, low-noise unit which is economical in local oscillator power. A prototype with a balanced mixer in strip line appears promising.

(*d*) *Data Processing*

Several projects already under way require the analysis of very large amounts of data, and the demand will increase when the giant radio telescope, with its high resolving power, becomes available during 1961. The analysis of these data can be handled very effectively on a modern high-speed computer, but to take full advantage of the computer, it is important that the original data be recorded in digital form on punched-paper tape or punched cards. A data-processing section has been formed within the radio astronomy group to develop and provide the necessary recording facilities, and undertake and advise on computing requirements.

During the year a digital recording system has been built and tested, which has a control unit designed primarily for multi-channel hydrogen-line work. The recording system uses 5-hole punched-paper tape and records each number as a 10-bit symbol coded in cyclic-progressive-binary code.

A transistorized version of this system is under construction. To this version an optional facility will be added by which the least significant digit can be discarded and replaced by an odd-parity bit to give an error-checking code.

A third recording system which is faster and more flexible than the other two has also been designed. This system will use a binary-coded decimal code and will provide monitoring, immediate print-out facilities, limited tape-editing facilities, and an optional error-checking code. Some parts of the new system have been ordered, and others are being made within the Division.

An observational program on the Magellanic Clouds using the first recording system will start in the immediate future. Arrangements have also been made to undertake several small projects so that the Section can gain a wide range of experience in analysis techniques before the giant radio telescope becomes fully operational.

(*e*) *Theoretical Studies*

(i) *Cosmical Electrodynamics*

A theory of geomagnetic storms has been developed which covers the storm-time variations (D_{st}). A mechanism in terms of growing electric space-charge clouds is suggested, the outermost lines of force of the Earth's field then being torn away to form a geomagnetic tail pointed away from the Sun.

The longitude-dependent (D_s) field is much more complex. It is largely concentrated near the poles and has three distinct phases, with different equivalent current systems. A semi-quantitative theory of these phenomena has been developed in terms of a "twist" type of hydromagnetic disturbance which is conducted into polar regions. The D_s current systems are ionospheric Hall currents, driven by different electrical fields associated with the twist.

Hydromagnetic theory has also been applied to interpret the effects of trapped (van Allen) radiation on the geomagnetic field at several Earth radii. The results have been used to provide a possible explanation of the field variations measured by a magnetometer carried in the second Soviet lunar probe.

(ii) *Ionospheric Refraction*

Formulae have been developed which give the apparent changes of position of cosmic radio sources at transit due to ionospheric refraction. These have been used to estimate ionosphere thickness from the difference between known and apparent positions of sources.

4. Radio Propagation

Survey of atmospheric radio noise levels in Australia at wavelengths used for broadcasting and high frequency communication has continued. This project aims to provide basic radio propagation data needed for the planning of radio communication or broadcasting services. The survey is a cooperative venture, with contributions from several members of the Consultative Committee on Radio Research, a Committee which brings together the principal organizations in Australia using radio communications and those engaged in radio research.

The Division continued to provide technical supervision of the operation of the survey, and carried out a program of calibration tests at each of the three stations currently operating in tropical latitudes.

During the year under review the Division also assumed responsibility for the routine reduction of the data and final analysis of the results.

5. Radio Navigation

Flight testing and development continued of the Bearing Measuring Equipment described in last year's report. Further tests were made with the aerial mounted on top of a water tower in the Katoomba area. Results indicated maximum errors of ± 5° and an r.m.s. error of less than 2°. Although this error is similar to that obtained at Hobart, the disturbance due to the mountains was less severe. A bearing indicator suitable for cockpit presentation was also tested during the Katoomba flights. The instrument included a bearing selector dial and tracking indicator.

The next stage of the work involves the testing of a prototype aerial design. This aerial is to be erected by the Department of Civil Aviation at Mascot Airport. Initial tests carried out on a 10 cm model of the aerial indicated that the radiation pattern should meet specifications set for the present Distance Measuring Equipment (D.M.E.) aerial.

A new bearing indicator based on digital circuits has been built and will be tested in conjunction with the prototype aerial tests. This instrument should be free of significant drift errors due to the use of the digital techniques.

6. Semiconductors and Transistors

(i) *Semiconductor Physics*

During the year a floating-zone silicon crystal grower was designed and partly constructed, crystals of germanium and silicon were grown with existing apparatus to meet the Division's requirements, and a number of diodes were constructed for tests with parametric receivers. Work was concluded on recombination radiation emitted from silicon containing a large excess density of carriers, in the presence of a strong electric field.

No further investigations will be undertaken by the Division in the field of solid-state physics.

(ii) *Transistor Circuit Development*

Two sets of Mk. II transistor D.M.E. have been completed, while a third set is awaiting testing. The first set is on loan to Amalgamated Wireless (Australasia) Ltd., who are producing the manufactured version. Initial deliveries to the civil airlines are expected in late 1961.

Excellent reliability has been obtained during some hundreds of hours of bench testing, the only semiconductor failures being in one type of special switching device used in the modulator. Other types will be tested to find a suitable replacement.

A precision current power supply, regulated to 1 part in 10^4, was produced for supplying a current of 2 A (at 120 V) to a maser magnet.

At the request of the Department of Civil Aviation the possibility of including two new features in the airborne D.M.E. set is being investigated. These features are required principally for air traffic control purposes.

The first possibility is a height over distance (H/D) facility, defining a series of straight and curved climb (or descent) paths, for locating the positions of aircraft from near the aerodrome up to their cruising altitude, i.e. up to 25,000 ft and out to 100 miles. The pilot may select slopes between 1 and 6° and minimum path heights from 0 to 8000 ft; his I.L.S. glide-slope meter is used to indicate the position of the aircraft relative to the selected path. The necessary circuits have been designed and included in the second transistor D.M.E. set. The equipment is at present installed in a Fokker Friendship aircraft and undergoing evaluation trials by the Department of Civil Aviation.

The second possibility is a high accuracy rate-of-closure meter, indicating to the pilot aircraft speed towards (or away from) a selected D.M.E. beacon. This would enable him to give the air traffic controller a more reliable "expected time of arrival". System design of such equipment is being studied.

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Upper Atmosphere Section

1. General

The Upper Atmosphere Section is concerned with the spatial environment of the Earth. It is currently studying the behaviour of the ionosphere, which is responsible for all long-distance radio communications, the emission of electromagnetic radiations from the high atmosphere and exosphere, and the upper atmosphere electric currents which are responsible for fluctuations in the magnetic field of the Earth.

Other groups in C.S.I.R.O. undertake research in fields closely related to the work of the Upper Atmosphere Section. The Division of Radiophysics studies the ionosphere, atmospheric radio noise, and other aspects of radio propagation; this Division is also engaged on a major research program in radio astronomy (*see* Chapter 44). The Division of Physics studies solar physics and solar radiation (*see* Chapter 42).

The Upper Atmospheric Section is currently enabled to carry out certain experiments in rockets and Earth satellites by courtesy of authorities which have these available. The Weapons Research Establishment at Woomera has available rockets suitable for this purpose, while the U.S. National Aeronautics and Space Administration has offered collaboration in experiments using Earth satellites.

Grateful acknowledgment is made of cooperation given to the Upper Atmosphere Section by the Postmaster-General's Department, the Weapons Research Establishment of the Department of Supply, the Bureau of Mineral Resources of the Department of National Development, and the Ionospheric Prediction Service of the Department of the Interior.

2. Ionosphere

(1) *Ionospheric Forward Scatter.*—This is a joint project carried out with the Postmaster-General's Department to test the suitability of a radio link between Hobart and Camden. Observations of the forward-scattered signal were continued until February 1960, when one year's continuous recording was completed. Pending the installation of telegraphic equipment by the P.M.G.'s Department,

continuous observations of the signal strength have been temporarily suspended. During the year's observations it has been found that the scatter signal strength is greatest in the summer months and weakest at the equinoxes. The median hourly signal strength is seldom less than 20 dB above the cosmic noise background and exceeds 40 dB on occasions. The signal is strongest around midday, tending to be a maximum before midday in the summer and after midday in the winter. The forward scatter signal may be temporarily enhanced above its normal strength by several causes. The most frequent are reflections from meteor trails. These increase the signal by 20–30 dB usually for about 3 sec. During the summer months strong reflections from sporadic *E* patches are common. These persist for up to 7 hr and give signal strengths of at least 80 dB above cosmic noise. The signals are usually unaffected by magnetic storms, but during severe disturbances the signal is increased.

(2) *Ionospheric Back Scatter.*—A fixed frequency back scatter sounder on 12, 18, and 30 Mc/s has been operated throughout the year. The 30 Mc/s sounder has been modified to enable a greater working range to be obtained and usable echoes can now be obtained from ranges of 20,000 km. A high-directivity antenna, 66 ft long, which has been constructed in the Section's workshop, will provide more accurate measurements of angle and direction of arrival of echoes. The peak output power of the 30 Mc/s transmitter has been increased to over 50 kW so that the high-frequency sounder is now a particularly versatile instrument. Projects to be investigated with it include transequatorial exospheric back scatter and long-range detection of auroral formations.

(3) *Theoretical Studies. Equatorial* F *Region.*—The afternoon electron densities above the equator are less than those in the subtropics, although it is at the equator that solar radiation is greatest. Mitra and Martyn suggested some years ago that this was due to the transport of ionization from the equator to the subtropics along the Earth's magnetic field. These suggestions had not been taken up by others to any great extent, and the equatorial *F* region has been generally regarded as anomalous. A study of I.G.Y. ionosonde data at these laboratories has shown that sporadic decreases of electron density at the equator coincide with sporadic increases at the subtropics, strongly supporting the idea of ion transport. Accordingly an investigation of this process has been made.

Beginning with the observed diurnal variation of the magnetic field at the equator, the electric current which, flowing in the ionosphere, could cause this variation, and the resultant movement of ionization under Ampere's law were deduced. It was argued that a downward movement of ionization would result in the loss of ionization by recombination, and that an upward movement of ionization would be followed by gravitation down the geomagnetic field lines producing a net transport of ionization away from the equator. On these bases the diurnal variation of height and electron density of the *F* region at the equator and the subtropics, the diurnal pattern of the correlation between daily fluctuations in electron density at the equator and subtropics, and the variation of electron density with latitude in the vicinity of the equator were calculated. The results of the calculations were compared with ionosonde data at all stages and the agreement appears to be good. It seems likely therefore that one of the major aims of the I.G.Y. ionosphere program, the solution of the "equatorial anomaly", has been attained.

3. Airglow

Airglow observations terminated in September 1959, 2½ years' data having been collected at this stage. Three papers arising from this work were published this year. The first reported the marked coincidence of subvisual aurorae detected by the airglow photometer, and bursts of radio noise recorded at 4.6 kc/s. These observations proved that kilocycle radio noise bursts have a cosmic, not merely an industrial, origin.

The second paper reported the detection of subvisual stable red auroral arcs on nights following active magnetic disturbance and aurorae. The existence of auroral arcs at middle latitudes during times of only moderate geomagnetic disturbance had not previously been reported, although confirmatory observations have now been made in France and America.

A paper collecting other results of the airglow observations is in print in the "Annals of the I.G.Y.". Some of the points presented here are:

(1) The green (5577 Å) airglow is independent of magnetic disturbance and is hence presumably not of auroral origin, but the red (6300 Å) has a strong auroral component.

(2) Dawn enhancement of the red airglow is very marked as early as 03 hr in winter. If this is a direct result of sunlight on the upper atmosphere, the atmosphere at heights of 2000 km must make an appreciable contribution to the 6300 Å airglow.

(3) There is no support for the view advanced by some overseas workers, that the red (6300 Å) airglow is simply related to the electron density and height of the *F* region of the ionosphere.

4. Very Low Frequency

(1) *General.*—Over 150 noise bursts and noise storms, similar in their amplitude variations to solar radio noise storms, were recorded at Camden. They were closely associated with disturbances of the geomagnetic field and with allied phenomena such as aurorae and airglow. Observations at Camden, Hobart, Adelaide, and Mundaring, W.A., showed that on most occasions the illuminated area of the Earth is patchy, with a geographical scale of 2000 km, and is stationary with respect to the Earth. However, during major magnetic storms amplitude variations at places 3000 km apart are synchronous and well correlated, and the geographical scale is much larger and probably of terrestrial dimensions. In addition, during major magnetic storms there is normally one isolated noise burst of several hours' duration occurring near sunset which appears to move in longitude at approximately solar rate.

The intensity of the radiation at 5 kc/s is between 10^{-17} and $10^{-20} W(m)^{-2}(c/s)^{-1}$.

(2) *Directional Observations*.—The very low frequency (V.L.F.) noise experiments have indicated that the apparent sources may be of limited geographical extent. To investigate this possibility more fully, an analysis has been made of the response of two common direction finders (a rotating loop and an Adcock) to sources of large angular size. In many cases the extent in both altitude and azimuth of the apparent sources can be obtained.

By using loop antennae rotating about a vertical axis, it was found possible on many occasions to determine the horizontal direction of propagation and to estimate the angular spread of the radiation. Observations at Camden, Hobart, and Adelaide permitted the location of the apparent sources of the radiation. On most occasions they were between 135 and 155°E. and at greater latitudes than 42°S. (51°S. geomagnetic). Approximately 20% were between 40 and 50° geomagnetic latitude. The average geographical size of the sources was 700 km. The study of the noise source pattern is of some interest because it may represent an image of the disturbed regions of the outer atmosphere.

(3) *Spectrum Observations*.—The majority of noise bursts were of narrow band-width (1.7 kc/s) centred at 4.6 kc/s. However, during considerable magnetic activity ($K_p > 6$) the upper and lower frequency limits extended higher and lower. During major magnetic storms the noise was detected from 1 to 40 kc/s. Discrete wide band bursts lasting a few minutes were observed towards the end of many noise outbursts.

(4) *Rocket and Satellite Flights*.—In the investigation of V.L.F. radio emissions from the Earth's outer atmosphere, many conclusions depend on the mechanism by which the noise is propagated not only through the ionosphere but also from the point of entry to the observing equipment. It is difficult for earth-bound equipment to resolve the several possible processes. A rocket-borne V.L.F. noise recorder, which will fly into and beyond the level at which noise penetrates the ionosphere, could provide valuable information about propagation. Such an experiment is in preparation. In the near future it is also proposed to fly V.L.F. noise equipment in a satellite orbiting the Earth to provide a world-wide picture of the noise reaching the top of the ionosphere. The rocket experiment will also be a proving flight for the satellite instruments. A completely transistorized noise recorder has been developed for the rocket experiment and a satisfactory ferrite loop aerial of small dimensions has been built. These will be submitted to the Weapons Research Establishment for environmental testing.

5. Micropulsations of the Geomagnetic Field

The propagation of hydromagnetic waves through the outer atmosphere was investigated by observing micropulsations of the geomagnetic field simultaneously at Hobart, Camden, and Townsville. Comparison of the micropulsation amplitude and period at these three places showed that there was no change in period with latitude, as had been suggested overseas. Calculation of outer atmosphere densities from such periods would be subject to considerable ambiguities.

6. Auroral Radiation at 75 and 40 Mc/S

Observations of auroral radiation at high frequencies were made at Hobart and Camden for comparison with the 5 kc/s emissions. The Camden measurements were made by using a large rhombic antenna installed by the Postmaster-General's Department for forward scatter tests. Polar absorption of cosmic radio noise following solar flares was detected with this antenna.

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Division of Meteorological Physics

1. General

The work of the Division of Meteorological Physics is directed to a better understanding of the behaviour of the atmosphere. Most human activity is in some way dependent on weather and climate, and meteorology as a public utility provides an increasing variety of services, for modern techniques in air transport, agriculture, and science. The effectiveness of these services must be based on a foundation of fundamental research into many physical processes in the atmosphere which still require clarification and solution.

Several other research groups within C.S.I.R.O. are undertaking projects related to meteorology or complementary problems such as water supply and conservation. The Division of Radiophysics is studying cloud physics and artificial rainmaking (*see* Chapter 44). The Division of Physical Chemistry is studying ice nucleation in relation to the precipitation of rain, and is also studying techniques to retard evaporation of water from dams and other storages (*see* Chapter 30). The Chemical Engineering Section is studying the desalination of water for agricultural or other industrial purposes (*see* Chapter 33). The Division of Mathematical Statistics is engaged in research on meteorological statistics (*see* Chapter 47).

Nearly all meteorological research is of a long-term nature and the pattern of study matures slowly. There have been no major changes during the year in the main areas of investigation of the Division of Meteorological Physics, which embraces selected problems ranging from the largest scale, which underlies the seasonal and world-wide variations in weather, to the smallest (or micro-meteorological) scale wherein lie many avenues for research affecting the growth and health of plants and animals.

The wider implications of the work of the Division outside the normal boundaries of meteorology are reflected in the Division's representation on the National Committees for Oceanography, Hydrology, Antartic, and Space Research. In the international sphere there has been work associated with the activities of the World Meteorological Organization, the International Association of Meteorology and Atmospheric Physics, the International Ozone Commission, and the International Antarctic Analysis Centre, and also U.N.E.S.C.O. and F.A.O.

2. Dynamic Meteorolgy

General circulation of the atmosphere is maintained by sources and sinks of energy located mainly in the tropics and polar regions. Australia's geographical position necessitates a thorough understanding of the dynamic influences of both the Antarctic sink and the tropical source regions. Geographically Australia is well suited for exploration of these influences. Observational data, especially that made available by the International Geophysical Year, has been awaited, in order to continue work initiated earlier on the nature of interactions in the general circulation. Three papers on this subject were contributed by officers of the Division at the Symposium of Antarctic Meteorology in 1959.

Meanwhile an assessment of the input of the several forms of energy in the layer from the ground to 10,000 ft has been completed for the Southern Hemisphere north of 65° latitude in January. This is a preliminary study in an attempt to evaluate the effects on large-scale motions, especially that of the heating due to the Australian continent.

Anomalies due to heating and cooling of the Australian and Asian continents, respectively, affect markedly the monsoons in the eastern hemisphere during southern summer. An assessment has been made of angular momentum balance for the equatorial trough zone, from a consideration of frictional torque of the monsoonal westerlies, and zonal and meridional stresses. This study is a prerequisite to exploring causes of variations in the onset of monsoon rain regimes, and its abruptness and subsequent pulsations. Vertical and horizontal distribution of easterly winds in the upper troposphere at low latitudes is a decisive factor in the mean and eddy transfers of angular momentum (vorticity), and thereby in changes of the monsoonal circulation.

Alongside these physical investigations, some empirical studies of long-period changes have continued. These were stimulated in particular by discoveries concerning effects of solar particles on various geophysical and astronomical phenomena. It has been known, for instance, that tropical surface temperature responds to the 11-year solar cycle. It is now found that this response has undergone slow change, most marked around 1920, presumably due to secular changes of tropical circulation.

On a smaller scale of phenomena, heating and turbulence, especially by their diurnal variations, strongly influence the behaviour of sea breezes and synoptic-scale cold fronts. Observations on frontal structure from the Renmark expedition in January 1959 have demonstrated, near the forward portions of such fronts, oscillations and circulations of considerable magnitude and of a period corresponding to that of the multiple disturbances often noticed at the ground. This sheds new light on the development of squall lines and pressure jumps. Field work has been resumed employing an aircraft and quick response equipment for measuring temperature and wind components. This should consolidate these studies and provide new information on the transfers of heat and momentum between the warm and cold air.

The broad features of the fronts studied so far agree well with the theoretical predictions from a consideration of frontal shapes in relation to surface stress (ground friction). This theory has been extended to take account of mass transfer through the front. Solutions were obtained representing damped oscillations and a series of gusts accompanied by pressure jumps.

Attempts are being made to assess eddy shearing stress by means of serial balloon flights simultaneously with micrometeorological measurement of surface stress under conditions of strong wind.

An instrument consisting of a modified radiosonde attached to a kite is being developed for measuring the detailed profiles of temperature and wind up to 2000 ft. A first model is at present on trial at Mawson by personnel of the Commonwealth Bureau of Meteorology, and improved equipment is being constructed for use in 1961. It is hoped to obtain information on the structure of the katabatic winds during these trials.

Following a request from the R.A.A.F., estimates were made of the average relationship between surface winds and winds at 1500, 3000, and 5000 ft, over the oceans within 1000 miles of the continent. This was required for estimation of surface winds from aircraft, to correct drifts observed by Doppler radar navigation.

3. Micrometeorology

Micrometeorology is the study of conditions in the air layers close to the ground, as determined largely by turbulence and radiation processes. Its scientific significance and practical importance to Australia through impact on agricultural science have been described in previous annual reports. The process of evaporation in particular becomes an economic problem wherever restricted supply demands efficient water usage.

Specialized equipment to measure and record the evaporation from natural surfaces has been developed (the "Evapotron"). This instrument comprises a suitably sensitive anemometer and hygrometer, the outputs from which are combined electronically on the eddy-flux principle to yield the evaporation as a dial reading on a meter. The present year has seen the successful completion of the proving field tests of the prototype instrument. Short-period evaporation over open grassland was directly measured to an accuracy of a few per cent. A transistorised version which is simpler and portable has been constructed. Field trials are due to begin with this model which it is hoped will provide the basis for ultimate commercial production of the evapotron.

Though designed specially for evaporation measurement, the instrument is readily modified to provide values of heat and water vapour flux for more fundamental studies of the mechanism of turbulent transfer. It has been so used during the past summer, with concurrent measurements of the detailed profiles of the relevant meteorological elements. This large body of data is now undergoing analysis.

Studies of temperature and wind profiles under varying degrees of atmospheric stability have continued. An analysis of the magnitude of temperature fluctuations as a function of height, wind speed, and stability has been completed.

In the Division and elsewhere a new approach has been developed to the estimation of turbulent transfer of heat, water vapour, and momentum. This is by way of structure functions, and preliminary assessment of the transfers by such methods show satisfactory results. The new technique promises to be much more suited to shipboard use than others now available.

The investigation on evaluation of evaporation from Lake Eucumbene has been brought to a satisfactory conclusion with the completion of the full analysis of the experimental data. Considerable confidence in the bulk aerodynamic method, recommended for routine use, is provided by the concordant results obtained from two independent methods, based on the heat budget and profiles respectively.

Construction of equipment for transferring turbulence records or other data in analogue form to digital form on punched paper tape is now almost complete. Special studies of turbulence and gust structure have been carried through for the Army Design Establishment and the Weapons Research Establishment.

4. Meteorology for Agriculture

This year the last two of the battery of 12 lysimeters set up to study the evaporation from different crops and soils under varying atmospheric and water supply conditions have been installed. Each lysimeter, a large concrete pot containing soil or water, sunk flush with the ground, weighs approximately 6 tons, and the water loss is to be measured by automatic balances. These balances are being designed and built in the Division's workshop. Four such instruments, capable of detecting a loss of 0.001 in. of water, have now been completed and tested.

Early results from balances already in use have demonstrated the need for corrections to the values of evaporation obtained from the common lysimetric technique (water input *minus* drainage) on which many previous conclusions have been based. Such errors may be significant for monthly and dominant for weekly periods, but the results from weighings and improved techniques of working up the data can overcome them. Analysis of the first full year of observations allows values to be tentatively assigned to the relative evaporation rates from water, bare soil, and short grass. A reasonably satisfactory degree of uniformity of "evaporative power" (including wind speed, temperature, and humidity) is being indicated from a continuing survey over the lysimeter site.

The investigation into the meteorological conditions associated with the infestation of tobacco crops by blue mould has been continued at Ovens, Vic., and at Mareeba, Qld., in cooperation with the Victorian Department of Agriculture and the Division of Plant Industry respectively. Results are consistent with indications of the previous season's work, that the incidence of conditions critical for the sporulation of the mould are related to atmospheric conditions around the crop. Study of a related problem — onset of dew deposition on a freely exposed lamina — has been continued. A grant received from the Central Tobacco Advisory Committee for use in 1960–61 will provide for improvement in instrumentation during the next season.

During the summer an investigation into the relationship of water loss from drying hay with meteorological conditions was undertaken in collaboration with the Fodder Conservation Section. Analysis of the observations is still in progress.

Irrigation is an accepted method of alleviating or preventing frost damage, but little quantitative work has previously been done on the effect. Comparative trials using various intensities of irrigation and measuring the response in air temperature were conducted in vineyards in the Merbein area in cooperation with the Commonwealth Research Station, Merbein, and the State Rivers and Water Supply Commission. The investigation will continue next spring.

A portable instrument to measure the amount of dew on natural grass is under development.

Construction and equipment, and general assistance and advice in micrometeorological problems have been provided to other bodies, in particular to the Divisions of Plant Industry and Land Research and Regional Survey. C.S.I.R.O., and the Horticultural Research Farm, Scoresby, Vic.

5. Radiation

The net radiometer previously reported, and now in commercial production, has been employed in further studies of the night cooling under clear skies of the first few metres of air above the ground. The investigation emphasizes the importance of radiative cooling of the air in the early stages of the formation of the nocturnal inversion, with application to the development of fogs and frost. It has revealed appreciable errors in standard radiation charts, due probably to underestimation of water vapour absorptivities used in their construction.

Recording of net, global, and diffuse radiation has been continued at Aspendale, and at Deniliquin and Alice Springs in cooperation with the Divisions of Plant Industry and of Land Research and Regional Survey respectively. These measurements have shown that Budyko's Atlas of Heat Balance substantially underestimates net and global radiation in the southern Australian region. Observations have continued at Mawson in collaboration with A.N.A.R.E and the Bureau of Meteorology.

A sensitive and simple electro-mechanical integrator has been developed and will be manufactured under licence. This instrument, though designed specifically for use with the net radiometer, is suitable for the integration of signals in the millivolt range from other types of equipment.

6. Ozone

Ozone measurements for collation in the global network inaugurated for the I.G.Y. have been continued at Aspendale, and in collaboration with the Commonwealth Meteorological Bureau at Brisbane. The instrument lost by fire at Macquarie Island will be replaced during the coming year, but its location remains to be decided.

A new absolute method has been developed for calibrating the wedges of the Dobson ozone spectrophotometer. Besides being quick and easy to apply, this new technique is more accurate than that formerly used.

7. Miscellaneous Studies

A strip chart recorder has been designed for long period operation and a prototype instrument has successfully completed 15 months of field trials. This instrument is capable of operating unattended for periods up to 12 months, and is intended for use in remote areas where it can provide records of river level, rainfall, temperature, etc. according to the type of sensing element coupled to it. Interest has been evoked by its possibilities, particularly amongst water supply authorities. Results of the preliminary trials indicate that the recorder represents a major improvement over existing instruments in low cost installation. At the same time it competes favourably in simplicity of design, ease of servicing (by unit replacement) in the field, linearity of scale with straight time ordinates, accuracy of time check of chart rate, and freedom from undesirable characteristics (such as ambient temperature effects). The recorder has been patented and commercial production of a limited number (12) is nearly complete. These are being purchased by interested authorities who have agreed to cooperate in a period of further operational testing and assessment before unrestricted commercial manufacture is approved.

Measurements of rainwater radioactivity have been continued at Aspendale. They have provided valuable information on the world-wide problem of how the debris, projected into the stratosphere at the explosion site, travels and spreads before finally falling to earth. Radioactive stratospheric clouds suffer only limited dispersion and retain their identity for several months. Evidence has been obtained of a poleward drift at stratospheric heights of order 1 m/sec.

Instruments embodying the transistor operated cup anemometer referred to in the last report have now been supplied to the Division of Plant Industry, the Tobacco Research Institute, and the State Electricity Commission.

An instrument to measure temperatures in ice boreholes is being developed for the Antarctic Division and the Meteorology Department, University of Melbourne. This will allow assessment of temperature gradients and the associated heat flows, important to the ice balance of the Antarctic continent.

Some special radiation and climatic studies were made for Mt. Stromlo Observatory to aid the search for new observatory sites.

Calibration services for anemometers and radiation instruments were maintained for outside users.

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Division of Mathematical Statistics

1. General

The principal functions of the Division of Mathematical Statistics are: fundamental research in various branches of mathematical statistics; and maintenance of a research service to provide other C.S.I.R.O. Divisions and Sections with specialized assistance in planning research and in analysis of experimental results.

There has been continued expansion in statistical work undertaken in collaboration with other Divisions and Sections, and the Division of Mathematical Statistics is now associated with practically every research activity of C.S.I.R.O. During the year under review the Division has established an additional centre at the National Standards Laboratory, Sydney, and the Division's staff in Canberra has been increased.

In addition to cooperative investigations within C.S.I.R.O., the Division has provided similar assistance to an increasing number of outside bodies, including Commonwealth and State departments, the Administration of New Guinea, private firms and companies, and the universities. Close liaison with the University of Adelaide, in particular, was strengthened further by two developments. Until such time as the University can appoint suitable staff, the Division assumed full responsibility for providing advisory service for the research staff at the Waite Agricultural Research Institute, and for the teaching of Biometry to students in the Faculty of Agricultural Science. In this connexion at the invitation of the University, the Chief is occupying the Chair of Mathematical Statistics, concurrently with his duties in C.S.I.R.O.

Early in 1959, Sir Ronald Fisher, F.R.S., a leading statistician from the United Kingdom, joined the Division as Senior Research Fellow for 6 months, spending most of his time in Adelaide, at Divisional Headquarters, but visiting nearly all C.S.I.R.O. laboratories. The principal object of his visit was to give a course of lectures and seminars in scientific inference. On terminating his Fellowship, Sir Ronald elected to reside in Australia, and is now working in an honorary capacity in the Division.

Considerable attention has been given to planning facilities for digital computing. A detailed survey of C.S.I.R.O.'s requirements has emphasized special features in this regard, namely:

(*a*) Widespread development of automatic recording of scientific data, specifically intended for treatment by digital computers;

(*b*) very diverse types of computing problems;

(*c*) the geographical distribution of C.S.I.R.O.

Specially qualified officers of the Division have designed an integrated system which will meet the exacting demands of the problem, and work is now proceeding on the programming details.

Computing itself continued on an expanding scale of CSIRAC at the University of Melbourne, and now the computer is occupied for 24 hr per day. Divisional staff continued to work on CSIRAC and collaborate with the staff of the Computation Laboratory, University of Melbourne.

In Adelaide, the Weapons Research Establishment, of the Department of Supply, continued to provide facilities for conducting a large-scale climatological study, by allowing the Division regular computing time on their rostered program for the use of WREDAC and its ancillary equipment, until the work terminated at the end of 1959.

2. Theoretical Statistics

The solution has been obtained of two long-standing distributional problems, in the application of the fiducial argument in scientific inference. These solutions provide the means for determining exact and accurate fiducial limits for parameters in testing compound hypotheses. The general fiducial distribution has been obtained for the following conditions:

(*a*) observations having different mean values but a common variance;

(*b*) observations drawn from the general multivariate normal distribution.

The sampling distribution of the two sample means, the variance, and the correlation coefficient has been derived for the particular case of a bivariate normal distribution with different means but having a common variance. Research on the generalization of this result for any number of variates is in progress, and the simultaneous fiducial distribution of the four parameters for the particular conditions of this case has been obtained.

Research continues on the theory of the analysis with incomplete observations. Accurate approximate methods have been devised for determining the expectation of mean squares in the analysis of variance of designs adapted for the recovery of interblock information. The accuracy of the approximations has been determined by comparing them with the exact value of the expectations obtainable by much more laborious procedures.

3. Meteorological Statistics

Statistical investigations to determine accurate methods for spatial prediction of rainfall have been completed.

The importance of this work arises from the rapid development of climatology in Australia, and its diverse applications, in the agricultural and pastoral industries, in engineering, and in soil conservation. The problem of accurately estimating the position of rainfall isohyets is complicated by the paucity of observing stations in this country. Two techniques have been perfected:

(*a*) Prediction in terms of position and altitude of observing stations suitable for regions up to 50 × 100 miles in area. This method was worked out in detail for the area in the immediate vicinity of Adelaide. The Engineering and Water Supply Department of South Australia has used the results in planning future expansion of the Adelaide metropolitan water storage.

(*b*) Prediction in terms of correlation with neighbouring stations, suitable for regions up to 200 × 800 miles in area.

The detail of this method was worked out on data from a region comprising parts of South Australia and Victoria. In addition to supplying a means of predicting rainfall at points where there are no observing stations, this investigation provided basic material for further study of the migratory anticyclones which traverse southern Australia from west to east, and so profoundly affect the rainfall of the region.

Investigations designed to develop accurate methods for the prediction of minimum temperature have been extended to data from Adelaide, Mount Gambier, and Oodnadatta.

Research has been initiated to devise methods for measuring the association of mean sea-level pressure patterns and temperature (dry bulb at 1500 C.S.T.).

4. Biometry

Research into methods for estimating the mean fibre diameter of wool on individual sheep continued. A new technique using standards has been devised, in connexion with the cast method, by which the so-called packing ratio can be assessed with ease and greatly increased accuracy.

Estimation of the cystine content of the serum in sheep's blood, by mixing serum with known amounts of radioactive cystine, has led to an interesting statistical problem on optimal design and estimation of a parameter by means of the ratio of two normal variables.

Further research has been completed in the critical analysis of the various laws advanced to provide a quantitative formulation for the influence of nutrition on plant growth. Allied to this work is the estimation of kinetic constants in enzyme studies.

The statistical analysis of experiments in microbiology such as irregularities in the rate of loss of virus rubbed on leaves of host plants, the density distribution of viral lesions within an assay plant, and the influence of various temperature and light effects on sporulation of a fungus, has called for special analytical techniques to overcome difficulties associated with this type of data.

Special sampling procedures have been designed for field studies of lerps, grasshoppers, and Queensland fruit fly, and for ecological investigations with other insect pests.

Sampling studies in relation to codlin moth infestation have been completed and published. These studies resulted in a modified form for Fairfield Smith's heterogeneity law for guarded plots.

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Industrial Research Liaison Section

1. General

This small Section is concerned with promoting the use by Australian manufacturing industries of the results of C.S.I.R.O. research; assisting expansion of research for industry, especially through sponsored research carried out in C.S.I.R.O. laboratories; helping to extend contacts between industry and the research units of C.S.I.R.O.; and providing assistance for cooperative industrial research.

The work of the Industrial Research Liaison Section is complementary to that of the Agricultural Research Liaison Section, which interprets results of C.S.I.R.O. research for the agricultural and pastoral industries (*see* Chapter 17).

2. Liaison Activities

The Industrial Research Liaison Section has continued to produce the bi-monthly publication *C.S.I.R.O. Industrial Research News.* This pamphlet presents the results of the C.S.I.R.O. research in non-technical language and places special emphasis on research developments reaching the stage of industrial application. It is circulated throughout Australian industry. Articles and extracts from *C.S.I.R.O. Industrial Research News* are widely reprinted in Australian and overseas trade journals, and in the press. The Section has also prepared special publications dealing with C.S.I.R.O. laboratories on the application of C.S.I.R.O. research. These have included a brochure on the "Wool Research Laboratories of C.S.I.R.O."

The program of C.S.I.R.O. is directed to the solution of basic problems affecting wide sections of industry, and it is not always possible to investigate problems that are of particular importance to specialized branches. Industrial groups and individual firms have in many cases provided financial support to expand the research program to cover fields in which they have a special interest. Research projects sponsored by industry in this way have become an established feature of C.S.I.R.O. activities, and the Section is concerned with making suitable arrangements for projects of this kind.

The Section deals with numerous technical inquiries, principally those in subjects not covered by research units of C.S.I.R.O.

The number of patents arising from research in C.S.I.R.O. is substantial, and some hundreds of patents and patent applications are now current, of which the majority are the subject of patent licence agreements. The Section provided assistance to Divisions with patenting and licensing problems, and with all aspects of the industrial application of patents. In collaboration with the Divisions concerned, the Section is responsible for the promotion of patented inventions, both in Australia and overseas. This constitutes one of the Section's major activities.

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Publications, Libraries, Films, Translation, and Overseas Liaison

1. General

The results of C.S.I.R.O. research are made available through various channels.

Formal scientific publication is supplemented by: preparation of films (*see* Section 3 of this Chapter); continuous and close contact with industry by officers of Divisions and Sections; provision of facilities for guest workers in laboratories; publication of trade circulars, newsletters, and articles in trade journals; press releases; lectures and short courses of specialized training; and organization of specialist conferences.

Application of research in primary industries is assisted by the Agricultural Research Liaison Section (*see* Chapter 17).

Application of research in secondary industries is assisted by the Industrial Research Liaison Section (*see* Chapter 48).

Liaison Offices are maintained by C.S.I.R.O. in London and Washington (*see* Section 6 of the Chapter).

Section 4 of this Chapter deals with the work of C.S.I.R.O. libraries and Section 5 with the work of the Translation Section.

2. Publications

The Australian Academy of Science continued to cooperate with C.S.I.R.O. to ensure maintenance of a high standard in papers appearing in scientific journals published by the Organization. These journals are:

Australian Journal of Agricultural Research	Six issues a year
Australian Journal of Applied Science	Issued quarterly
Australian Journal of Biological Sciences	Issued quarterly
Australian Journal of Botany	Issued as material becomes available
Australian Journal of Chemistry	Issued quarterly
Australian Journal of Marine and Freshwater Research	Issued as material becomes available

Australian Journal of Physics	Issued quarterly
Australian Journal of Zoology	Issued as material becomes available

General editorial policy is decided by a Board of Standards comprising: Sir Macfarlane Burnet (Chairman), Dr. N. S. Noble (Editor), Professor J. S. Turner, Professor W. P. Rogers, Professor N. S. Bayliss, and Dr. J. L. Pawsey. Advisory committees are responsible for editorial matters affecting each individual journal, and members of the Board serve on appropriate journal committees.

The Royal Australian Chemical Institute collaborates in the publication of the *Australian Journal of Chemistry*; the Institute of Physics (Australian Branch) collaborates in the publication of the *Australian Journal of Physics*; and the Australian Veterinary Association and the Australian Institute of Agricultural Science collaborate in the publication of the *Australian Journal of Agricultural Research*.

The journals listed above are open to receive contributions of merit from research workers, irrespective of country or establishment to which they are attached. Many papers have been published from workers in Australian universities and a limited number from overseas sources.

Results of C.S.I.R.O. research are published in these journals, in bulletins, in technical papers of the Divisions and Sections, and in special series such as the "Land Research" series and the "Soil Publication" series. Many research papers are also contributed by C.S.I.R.O. officers to specialized scientific journals both in Australia and overseas.

A complete list of scientific papers published during the year by C.S.I.R.O. officers will be found in Chapter 3 of the Twelfth Annual Report.

3. Films

The following films were completed and released by the Film Unit during the year:

"Pattern for Progress".—16 mm, colour, sound, screening time 20 min. Produced for the Agricultural Research Liaison Section, this film was made in collaboration with the New South Wales Department of Agriculture. It is an extension film, treating the Yass River Valley Project as an example of the need for, and what can be achieved by, cooperation between scientists, extension officers, and farmers.

"The Biological Control of Insects".—16 mm, colour, sound, screening time 36 min. Produced in collaboration with the Division of Entomology, this film shows the entomologist's work in controlling insect pests by the use of their natural enemies. Features of insect behaviour are recorded by close-up photography. Although the film is intended primarily for biologists, the commentary has been designed for the educated public. The film was entered in the 1960 Australian Film Competition, conducted by the Australian Film Institute, and won the highest award, a Silver Medallion, in the Teaching Section.

"Evaporation Control".—16 mm, colour, sound, screening time 6½ min. Produced in collaboration with the Chemical Research Laboratories, this film describes a newly developed method of reducing evaporation losses from large reservoirs with a film of cetyl alcohol, applied in powder form from a boat.

The following films are due for early release: "Challenge of the North — The Katherine Area"; "Dangerous Immigrant"; "Sheep Selection"; "Cattle for the North"; "Rainmaking"; "Bird Banding".

Increasing advantage has been taken of television to bring C.S.I.R.O. research programs before the general public. One 3½ min film was produced expressly for release on television (and shown in Melbourne on ABV-2 and GTV-9), and excerpts from "The Mallee Fowl", "The Mutton Birds of Bass Strait", "The Biological Control of Insects", "Evaporation Control", and the existing record material on the "Belmont" cattle breeding experiments were used in network programs and news reviews throughout Australia. Excerpts from "The Mutton Birds of Bass Strait", "The Mallee Fowl", "Storms on the Sun", "Radio Astronomy in Australia", and the existing record material on "Rainmaking" were also incorporated in programs originating from the Canadian Broadcasting Corporation, the Columbia Broadcasting System of the U.S.A., and the British Broadcasting Corporation and Associated Television.

The indexed catalogue of C.S.I.R.O. film productions, scheduled for release during the 1959–60 period, has been re-edited and will be issued in printed form in October.

4. Libraries

The libraries continued to develop and expand various projects to increase their service to officers. Incorporation of the Union Catalogue of Scientific and Technical Periodicals in the Libraries of Australia into an up-to-date loose-leaf volume entitled "Scientific Serials in Australian Libraries" was completed during the year. The total work now comprises approximately 24,000 titles and covers entries from 316 libraries.

Circulation of C.S.I.R.O. Abstracts continues to increase and has now reached approximately 600. The section listing translations was enlarged in 1960 to include translations available from other Australian organizations. This has rendered it a more useful finding list for research workers.

Author and subject indexes have been included in the Australian Science Index since the first issue of the current year, and cumulations of these indexes will in future be published at the end of each year.

An index, formerly compiled and issued as a separate mimeographed publication to the List of Publications, has now been incorporated in the list itself. This should make the work of C.S.I.R.O. more easily accessible, both to inquirers within and outside C.S.I.R.O.

There have been relatively few staff changes in the libraries and no new libraries have been established. Effective use of the new union list will enable the libraries to concentrate on the really important job of consolidating collections and filling gaps in the scientific holdings, thus avoiding unnecessary accumulation so expensive of time and space.

5. Translation

The Translation Section has carried out translation, written, oral, and recorded, as required by Divisions and Sections. For the year 1959–60 there were 492 requests for translation other than oral translation, compared with 458 for 1958–59.

The Section has operated as Australian agent for the Index of Translations of the British Commonwealth Scientific Office, and has supplied copies of its own written translations to the United States Office of Technical Services.

The languages handled within the Section were German, Dutch, Swedish, Norwegian, Danish, French, Italian, Spanish, Portuguese, Russian, Czech, Polish, Ukrainian, and Slovene. For other languages outside translators were used.

6. Overseas Liaison

C.S.I.R.O. has Scientific Liaison Offices in London and Washington as constituent units of the British Commonwealth Scientific Office (London), and the British Commonwealth Scientific Office (North America). These offices maintain close contact with overseas scientific developments and serve as centres for visitors, research students, and visiting scientists. The Chief Scientific Liaison Officers in London and Washington have represented Australia at scientific conferences in the United Kingdom, Europe, and the United States of America. The London Office has materially assisted in the recruitment of research staff from the United Kingdom and European countries.